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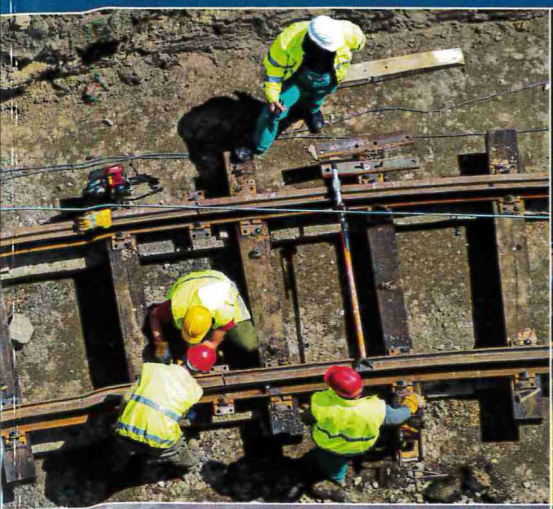
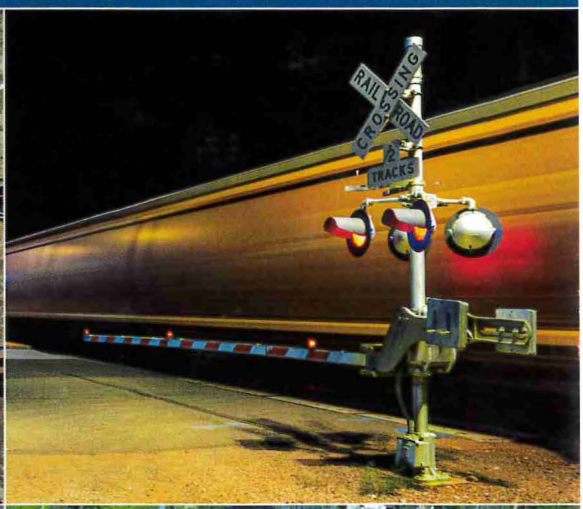
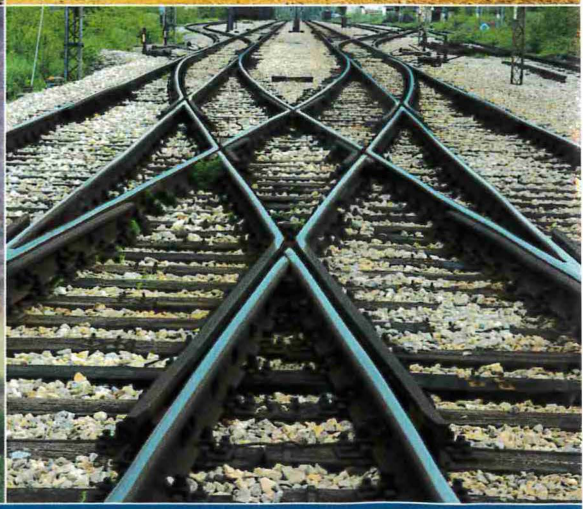
CONSENSUS STUDY REPORT

Review of the Federal Railroad Administration's Research and Development Program







TRANSPORTATION RESEARCH BOARD
SPECIAL REPORT 334

Review of the Federal Railroad Administration's Research and Development Program

Committee for a Review of the Federal Railroad Administration's R&D Program

A Consensus Study Report of
The National Academies of
SCIENCES • ENGINEERING • MEDICINE

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COMMITTEE FOR A REVIEW OF THE FEDERAL RAILROAD ADMINISTRATION'S R&D PROGRAM

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Preface

The Federal Railroad Administration (FRA) Office of Research, Development, and Technology (RD&T) has engaged the Transportation Research Board (TRB) of the National Academies of Sciences, Engineering, and Medicine (the National Academies) since the 1990s to provide a review of its research services and products. The first review was requested by Congress in 1995. Since then, TRB study committees have conducted several additional independent reviews of the RD&T program at the request of FRA. In 2018, RD&T commissioned this study charged with "validating FRA's process to identify new priorities for addressing emerging safety issues and trends, and evaluating the feasibility, usefulness, effectiveness, and impact of R&D products and services in railroad safety." The study charge is presented in full and discussed in Chapter 1.

To conduct the study, TRB convened a committee of experts whose fields range from railroad engineering, safety assurance, and R&D program evaluation to human factors, railroad management, and labor. Led by John M. Samuels, Jr. (National Academy of Engineering), President of Revenue Variable Engineering, LLC, the committee members authored the report's conclusions and recommendations through a consensus effort while serving uncompensated in the public interest. Biographical information about the committee members appears at the end of the report.

ACKNOWLEDGMENTS

The committee thanks the many individuals and organizations who contributed to its work.

The FRA liaison for the study was Tarek Omar, Program Manager, Rolling Stock Division, who provided contract oversight and handled information requests from the committee. Maryam Allahyar, Director, RD&T, briefed the committee on the study charge and the R&D support functions. The committee was briefed by or received information from the following FRA officials: Sam Alibrahim, Gary Carr, Leonard Evans, Gary Fairbanks, Les Fiorenzo (retired), Frank Frey, Michele Geary, Francisco González, Jeffrey Gordon, Michail Grizkewitsch, Francesco Bedini Jacobini, Starr Kidda, Miriam Kloeppel, James Payne, Ali Tajaddini, and Khaled Zaazaa.

The committee's review of the four research divisions benefitted from input of many industry experts, some of whom contributed in more than one area. For track and structures, the committee heard from Mehdi Ahmadian, Virginia Polytechnic Institute and State University; Riley Edwards, University of Illinois at Urbana-Champaign; Jeff Moller, Association of American Railroads (AAR); Brenda Moscoso, AAR; Melody Sheahan, AAR; and Allan Zarembski, University of Delaware. For human factors, the committee was briefed by Carl Belke, D&H Rail Consulting LLC; Lawrence Fleischer, BNSF Railway Company (BNSF); Muriel Friday, Capital Metropolitan Transportation Authority; Kirk Gill, Canadian National Railway (CN); Ken Glover and Eric Holton, Genesee & Wyoming Inc.; Hilary Konczal, Metra; Alex Lang, Carload Express, Inc.; Andrew Liu, Massachusetts Institute of Technology; Joshua McCormack, Maryland Department of Transportation; Tom Meierhoff, Iowa Interstate Railroad; Jason Myers, Norfolk Southern Railway (NS); Aaron Ratledge, BNSF; Lisa Staes, Center for Urban Transportation Research, University of South Florida; Tim Tenne, Amtrak; and Justin Vonashek, Metro-North. For rolling stock, the committee was briefed by Christopher Barkan, University of Illinois at Urbana-Champaign; Dean Del Peschio, MARC Train Service; Hai Huang, Penn State Altoona; Ron Hynes, AAR; Darrell Iler, CN; and Michael Trosino, Amtrak. For train control and communications, the committee received input from Gail Bickerstaffe, Canadian Pacific Railway; Joseph Brosseau, AAR; Eric A. Hullemeyer, NS; Michael R. Newcomb, Union Pacific Railroad; David Olson, CSX Transportation; Tim Pulak, CN; Narayana Sundaram, American Public Transportation Association; Ed Tilley, BNSF; and Doug Vogl, Kansas City Southern Railway.

Serving as the study director, Micah D. Himmel, TRB, managed the study and drafted the report under the guidance of the committee and supervision of Thomas R. Menzies, Jr., Director, Consensus and Advisory Studies, TRB. Karen Febey, Senior Report Review Officer, TRB, managed the report review process. Michael Covington, Senior Program Assistant, TRB, provided administrative and logistical support. Anusha Jayasinghe, Associate Program Officer, TRB, and Claudia Sauls, Program Coordinator, TRB, assisted in preparing the report for publication.

This report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. The purpose of this independent review is to provide candid and critical comments that will assist the National Academies in making each published report as sound as possible and to ensure that it meets the institutional standards for quality, objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

The committee thanks the following individuals for their review of this report: Roger McCarthy, McCarthy Engineering, Palo Alto, California; Ann Mills, Rail Safety and Standards Board, London, England; Dimitris Rizos, University of South Carolina, Columbia; and Howard Stone, Princeton University, Princeton, New Jersey.

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations of this report, nor did they see the final draft before its release. The review of this report was overseen by Chris T. Hendrickson (National Academy of Engineering), Carnegie Mellon University (emeritus), and Craig E. Philip (National Academy of Engineering), Vanderbilt University. They were responsible for making certain that an independent examination of this report was carried out in accordance with the standards of the National Academies and that all review comments were carefully considered. Responsibility for the final content rests entirely with the authoring committee and the National Academies.

Contents

Summary

The Transportation Research Board (TRB) formed the Committee for a Review of the Federal Railroad Administration's (FRA's) R&D Program at the request of FRA's Office of Research, Development, and Technology (RD&T) for strategic feedback on the program. RD&T asked that particular attention be given to strategic planning, means for setting priorities, stakeholder engagement and communications, and project and program evaluations. This is the seventh TRB review of the RD&T program and the first since 2015.

The RD&T contract research portfolio is programmed and administered by four research divisions covering the major railroad engineering disciplines: track and structures, human factors, rolling stock, and train control and communications. The committee divided into four subcommittees consisting of subject matter experts to review the work of the four divisions by considering the safety needs they address, querying their leadership and staff about methods used for selecting research topics and managing projects, consulting with stakeholders familiar with each division's work, and sampling a handful of projects. The committee reconvened as a whole to consider the results of the division reviews and examine RD&T's support functions.

RESEARCH DIVISION REVIEWS

Alignment of Research with Incident Causes

On the whole, the four research divisions do a good job programming research that addresses railroad safety problems and causal factors identified

from FRA incident data. A theme that characterizes the Track and Structures Division's (Track Division's) portfolio is innovation in track inspection capabilities to detect track component defects, the top cause of track-related derailments. Railroad worker fatigue, a well-established cause of derailments and evident in the number of incidents attributed to excess speed and switch run-throughs, is a focus area of the Human Factors Division. A large portion of the Rolling Stock Division's portfolio addresses wheel, bearing, and other truck and suspension system failures that are major causes of train derailments attributed to locomotive and railcar equipment and components. While much of the research in the Train Control and Communications (TCC) Division's portfolio supports the statutorily required implementation of positive train control (PTC), it devotes the balance of its portfolio to research aimed at reducing the large number of reported grade-crossing and trespasser fatalities.

Other Considerations When Programming Research

In addition to prioritizing and programming research informed by incident data, each of the four research divisions takes other considerations into account, including the interests and needs of industry, other FRA offices, Congress, and other stakeholders. They do so in a generally balanced way, which can be challenging given their discretionary budget constraints.

All four divisions make a concerted effort to engage with the railroad industry, consulting regularly about research needs and partnering in the conduct of research. By connecting with industry, the divisions hope to ensure that their research projects meet practical needs and produce usable results that increase safety, while also minimizing the potential for duplication of effort and augmenting program budgets to leverage industry contributions. Although the level of industry engagement is not consistent across the four divisions—and some additional engagement and communications activity may be desirable for reasons observed below—the committee's impression is that industry outreach and collaboration is a strong suit of the RD&T divisions. It is notable that the Human Factors Division has developed a strategic plan for the Cab Technology Integration Laboratory (CTIL) to place greater emphasis on industry consultation, collaboration, and communication, which was identified as a key need in the previous TRB review.

The four research divisions also view other FRA offices as customers of their research, while also responding to legislative direction. The Track Division has a direct role in supporting the regulatory and enforcement needs of the Office of Railroad Safety (RRS) through its projects on inspection technologies, and the Rolling Stock Division conducts research to inform rulemaking on tank cars, the transport of hazardous materials, and other related topics. Congress has directed research in the Rolling Stock Division to improve

the safety of passenger railcars and in the Human Factors Division through dedicated funding for the Short Line Safety Institute (SLSI), which seeks to measure and improve the safety culture of short line and regional railroads.

External Views

To obtain insight on how others view the relevance, impact, and reach of the four divisions' work, the subcommittees consulted with researchers who have worked on projects, freight and passenger railroad industry representatives, and FRA officials from other offices. The commentary was largely positive, as the work supported by the divisions was frequently described as high quality, relevant to industry needs, and likely to produce safety benefits. For example, the Rolling Stock Division's wheel research program was lauded for having made valuable contributions to understanding wheel failure mechanisms; the TCC Division's research on PTC was described as addressing industry needs to expand the capabilities and improve the overall performance of this technology; and the Human Factors Division's work on suicide and trespasser countermeasures was characterized as timely and helpful for addressing these vexing safety problems.

Among the concerns that surfaced in discussions with industry, as noted in observations below, were criticisms about the slow and inconsistent process for publishing research, the sometimes limited communication of ongoing work and results, and the slow pace of some work, which in certain cases was attributed to the practice of dividing, or phasing, topics into multiple projects spread over several years. The phasing of projects into 1- and 2-year performance periods was also viewed by some academic researchers as problematic for attracting doctoral students, which is desirable for building the railroad research and engineering talent pool. Some researchers also commented on the need for more opportunities to work on basic research and propose research on cutting-edge or novel solutions to safety problems.

Division-Level Observations and Advice

Track and Structures Division

The committee observes the efforts made by the Track Division to identify research needs based on a combination of safety data, industry consultation, and collaboration. The division appears to place a heavy emphasis on proposals that involve partnerships and collaborations with railroads, suppliers, RRS staff, and other potential users of the results. The willingness of stakeholders to participate in this way increases the likelihood that the research will address practical problems and lead to innovations that

will have application in the field. Advance planning to assure widespread deployment capability is also evident in the selection of projects and by the frequent partnering of research contractors with industry. Even though the division plans for deployment, an observed need is for even more front-end technology transfer planning to avoid deployment obstacles, such as those that have arisen from assignments of user and intellectual property rights.

In accordance with these observations, **the Track Division should ensure that technology transfer planning is sufficiently thorough and anticipatory at the outset of projects to take into account and manage the challenges that can hinder desired levels of deployment of research products and services, including the management of intellectual property such as user and data rights.**

Human Factors Division

The committee observes that several of the programs and projects of the Human Factors Division are coordinated effectively through partnerships with and implementations by railroads toward achieving desired safety benefits, including the trespassing and suicide countermeasures program and the work of the SLSI. The strategic plan for CTIL, which calls for increased collaboration with industry, should help ensure that this world-class human factors laboratory is used to the maximum extent to address critical safety issues such as worker fatigue, effective application of automation, and improvements in human–technology interfaces and integration.

An observed need is for the division to match its high-quality work with a similar high-quality capability to communicate and disseminate the results and to tap a larger audience for its work, including the U.S. rail transit and highway sectors. Some longer-duration projects might also be desirable to attract doctoral students to projects, such as those performed using CTIL.

To expand its reach and influence, **the Human Factors Division should (1) become more involved in the design, development, and programming of research projects across FRA's RD&T portfolio; (2) engage more frequently with other U.S. Department of Transportation (U.S. DOT) modal administrations and other relevant federal agencies to identify opportunities for its work to inform, and be informed by, their human factors–related challenges and research; and (3) collaborate on the design and conduct of relevant research and the dissemination of those research results and products that have broad, multi-modal application.**

Rolling Stock Division

The committee observes that the Rolling Stock Division, perhaps more than the other divisions, covers a wide safety domain that demands consideration

for and balance of multiple interests when programming research. It also observes that because of this wide span of interest, industry consultation, communication, and collaboration are critical to ensuring that the division's research capacity is used to its greatest advantage.

With these observations in mind, the committee recommends that to better ensure that its projects not only align with the most important safety problems but also focus on research needs that are best suited to the unique strengths of a government contract research program, **the Rolling Stock Division should make industry consultations and collaborations a core feature of all research that will ultimately require industry acceptance and application of the results. In having so many diverse research responsibilities, such an alignment and focus is essential to ensuring the effective and judicious use of the division's limited research budget. Moreover, the division should prioritize projects based on safety data; these priorities should be used to determine the number of active projects commensurate with the division's funding level and allocated personnel.**

Train Control and Communications Division

The committee observes that the work by the TCC Division to improve the operational capabilities and performance of PTC aligns with its safety mission. It also observes that the division's focus on automation, intelligent transportation systems, communications, and sensor technology recognizes the importance of human factors to train operations and grade-crossing safety. Having such a wide breadth of responsibility—from furthering PTC to grade-crossing safety—the division has demonstrated creativity in harnessing these technologies to address human performance and behavior issues that can affect safety.

An observed need is for the TCC Division to ensure that the results of its research are published and disseminated faster, which is especially important for ensuring the timely application of the division's advanced technology–oriented work. To this end, **the TCC Division should make a concerted effort to ensure that research results are made available to industry and other users as quickly as possible to contribute to the advancement of PTC and other systems being deployed in the field.**

REVIEW OF R&D SUPPORT FUNCTIONS

Asked to review the support provided by RD&T for strategic planning, communications, and evaluation, the committee met with RD&T's senior management and division chiefs to discuss these functions and reviewed relevant planning and budgetary documents. In inquiring about the status of RD&T's strategic planning, the committee was told that a late-stage draft

of the FY 2018–2022 strategic plan was pending internal review, and thus might not be available during the study period. On the basis of these briefings and limited document reviews, as well as insights gleaned about the effectiveness of these support functions from the division reviews, the committee offers the following observations and advice with respect to RD&T's strategic planning, communications, and evaluation support functions.

Observations and Advice

Strategic Planning

Absent the availability of an up-to-date strategic plan during the study committee's deliberations, the committee examined RD&T's FY 2013–2017 strategic plan, assuming that RD&T may be using it as a model for the pending strategic plan and that it continues to exert influence over the existing program. As a model for future strategic planning, the committee finds both strengths and weaknesses in the FY 2013–2017 plan. The articulation of stakeholder communication and partnering strategies are strengths. The plan identifies key stakeholders who should be engaged, both inside (e.g., RRS) and outside (e.g., passenger and freight railroads, labor, and suppliers) of FRA. In addition, the plan contains well-reasoned strategies for identifying research needs and prioritizing projects, such as the importance of using incident data and consulting with RRS when identifying safety research needs and developing project concepts.

The FY 2013–2017 strategic plan is weaker in some other respects. Notably, it lacks explanations for procurement and evaluation strategies and thorough planning for technology transfer of research products and services. For instance, the plan does not explain why or when Broad Agency Announcements should be used as the means for procurement or when phasing of contract research into a series of smaller projects is warranted. The plan does not address advance planning for technology transfer, including means for addressing important issues such as the management of user and intellectual property rights. More generally, the plan does not offer compelling articulation of the role and value of FRA's RD&T, including the range of outcomes intended, which presumably consists of not only technology development to enhance safety but also information for decisions, operational solutions to problems, knowledge to support future research, technology transfer, and the development of a skilled pool of railroad safety researchers.

Inasmuch as the strategies espoused are likely to involve interests outside RD&T, including other FRA offices, the railroads and their suppliers, labor, and the research community, the opportunity for them to have input

into the plan at a formative stage is essential, but not evident in the FY 2013–2017 strategic plan.

RD&T should engage in ongoing strategic planning that not only articulates agency priorities, strategies for pursuing them, and justifications for its programs and budgets, but also clearly defines the support functions that are its responsibility and explains how those functions will be implemented. The plan should provide strategies for nurturing new technologies and techniques, such as the application of machine learning to railroad applications. The plan should also provide direction for assessing the impact of the research program over time, such as for the period covered by the most recent strategic plan, and it should articulate strategies for future impact assessments. Because many of the strategies in the plan are likely to involve interests outside RD&T, including other FRA offices, the railroads and their suppliers, labor, and the research community, such stakeholders should be formally invited to offer input early in the planning process.

The practice of phasing research, while conferring several benefits such as providing checkpoints on the satisfactory conduct and utility of the work, can lead to delays in the conduct of research and a larger administrative and oversight burden that can slow the development and deployment of important safety products and knowledge.

RD&T should make more judicious use of phased project procurement to ensure that valuable research results from well-scoped, low-risk projects are not delayed as a result of multiple procurements and that the number of projects under contract does not create oversight and administrative burdens that risk delays across the portfolio.

Note: While the study committee's report was in peer review, RD&T released its Research, Development, and Technology Strategic Plan for 2020–2024 (Federal Railroad Administration Office of Research, Development, and Technology 2020b). Unfortunately, the release occurred too late in the study process for the committee to thoroughly deliberate over and critique the document. One general observation that can be made, however, is that the strategies identified in the plan are similar to those of the earlier plan, with the exception of a new strategy for addressing safety risks in rural areas. A notable improvement is the inclusion of benchmark safety outcomes or goals as well as other metrics to evaluate a project's success, such as reduce the cost per mile of recording track conditions. Apart from these observations, however, the updated plan does not appear to address the points raised above in the recommendation. It also bears noting that for 3 years RD&T has not had the benefit of this refreshed strategic plan.

Communications

Both in planning documents and from discussions with senior management, stakeholder communications was described as integral to the program because of the benefits for priority setting, project management, and dissemination and communication of research results. Providing multiple channels for the broad array of stakeholders to communicate their research needs was characterized as critical to ensuring that the right problems are being targeted for research and that appropriate research mechanisms and procurement methods are being used. Communications was also described as being incorporated into the entire project life cycle to ensure that the work is being done well and that the results will be used in the field to yield positive safety impacts.

The committee was told that the RD&T division staff have been directed to evaluate the progress of the research and usefulness of the results on an ongoing basis by partnering with stakeholders in the conduct of the work and by making a coordinated effort to disseminate the results to the railroad community. The committee's review of the work of the four divisions suggested that this direction is being followed, but gaps surfaced in certain aspects of communications, particularly in the area of dissemination, such as hastening publication review and enhancing the office's electronic library (FRA's eLibrary), which may warrant attention and support from senior management.

RD&T senior management described the approach to communications within FRA and with the railroad industry through examples of the individual divisions engaging with railroads and suppliers. RD&T has conducted periodic informal meetings for years with colleagues in RRS, but since 2017 these meetings have been scheduled on a regular basis to discuss safety and research needs. The subcommittees found many examples of engagement with the railroad industry when reviewing the work of the four divisions. The examples cited in the report show a wide variety of approaches being employed, including RD&T staff participating in Association of American Railroads and American Public Transportation Association research and technical committee meetings and staff presentations at industry conferences.

In the absence of an updated strategic plan, however, it proved difficult for the committee to assess the role that the RD&T management team plays in supporting communications. The senior management team could be proactive in trying to identify where additional communications efforts are desirable and provide the needed guidance and resources to support and sustain them.

RD&T should consult the four research divisions about their communications needs and challenges and look for opportunities where support

by the management team would be advantageous, such as in providing resources for staff travel and participation in industry conferences and for convening annual, multi-day stakeholder workshops for sharing research results, identifying and prioritizing research needs, and exploring opportunities for collaboration in the conduct of research and in the demonstration and deployment of research results.

Evaluation

RD&T senior leadership and its divisions depend on close connections with stakeholders to ensure that the work is relevant, remains on course, and has impact when completed. The committee agrees that stakeholder connections are a necessary means for evaluating relevance and impact in large part because they ground the research program in reality and thereby provide a form of built-in evaluation. The four research divisions appear to ably develop and sustain such connections, which has yielded many deployable products for improving railroad safety. However, there are many reasons for engaging in formal and deliberate evaluations and for not relying solely on this built-in process for ensuring program effectiveness. One practical reason is that FRA research seeks to do more than develop deployable safety-enhancing products, services, and operational concepts.

While responsibility for undertaking program-wide evaluations clearly lies with RD&T divisions, the management team can also support the divisions in conducting their own program and project evaluations. The FY 2013–2017 strategic plan is short on details describing how RD&T senior management engages in and supports program and project evaluations. The committee learned that the management team has been building internal capabilities for program evaluation to ensure that projects have the highest probability of delivering benefits, but few additional details were provided on the status and accomplishments of this initiative. A general sense of the committee is that the management team is interested in conducting more informative evaluations as well as providing the divisions with more guidance and capacity for conducting their own evaluations, but it lacks the needed expertise in the field of research performance management and program evaluation.

RD&T should work to develop a more comprehensive approach to program and project evaluation, including the development of a common evaluation framework that can be used by the four divisions to assess outputs, outcomes, and ultimate safety impacts of their work. FRA should adopt best practices that become apparent through periodic benchmarking exercises with other agencies in U.S. DOT and other federal research agencies about their research program evaluation methods and support functions, including the Federal Highway Administration.

1

Introduction

The Federal Railroad Administration's (FRA's) Office of Research, Development, and Technology (RD&T) asked for this National Academies of Sciences, Engineering, and Medicine (the National Academies) review of the products and services that RD&T provides to other divisions of FRA and the railroad industry in accordance with its mission to ensure the safe, efficient, and reliable movement of people and goods by rail through applied research and the development of innovations and other solutions. Specifically, RD&T asked the National Academies' Transportation Research Board (TRB) to convene a committee of experts to review the quality and relevance of RD&T's current and planned research portfolio and to provide advice on strategies to better identify research needs, conduct high-quality research, and ensure that research products contribute to FRA's primary goal of improving railroad safety.

FRA oversees the safety of the nation's commuter and intercity passenger railroads, which have carried about 680 million passengers per year, and freight railroad system, which has transported about 1.4 billion tons of freight per year on more than 135,000 miles of track (Bureau of Transportation Statistics 2020a,b; Federal Railroad Administration 2020a). To support FRA's mission, RD&T seeks to deliver high-quality and impactful research results covering four main areas: track and structures, human factors, rolling stock, and train control and communications. This research, which is carried out by contractors that include railroad operators, consultants, university researchers, and technical experts from other research institutions, is guided by a 5-year strategic plan.

RD&T requested this review specifically to provide strategic feedback, including feedback on the effectiveness of its research R&D support functions (i.e., planning, communications, and evaluation). The full study charge, or Statement of Task, is shown in Box 1-1. It contains a series of questions pertaining to the quality, relevance, and impact of the program. Some of the questions concern the performance of RD&T's divisions responsible for each of the four main areas of research. They ask whether the division has

- Excelled in engaging, maintaining communication with, and using inputs from the full range of stakeholder groups (Question 1);
- Excelled in conducting and using results from needs assessments and diagnostic studies to prioritize, focus, and plan projects and programs (Question 2);
- Demonstrated sufficient flexibility and responsiveness to address changing economic, political, social, and technological contexts (Question 4);
- Produced high quality work that is appropriate and feasible for implementation (Question 7);
- Ensured that its R&D services and products are being used by FRA and the railroad industry (Question 8); and
- Helped the railroad industry improve safety and reduce fatalities (Question 9).

Other questions concerning R&D support functions ask whether RD&T

- Engages in planning that is guided by a well-defined mission with associated goals and priorities that reflect safety needs in the railroad industry (Question 3);
- Takes steps to evaluate and ensure the usability and likelihood of adoption of research results by the railroad industry (Question 10);
- Assesses the overall impact of the research and communicates the results to key stakeholders using means such as summative evaluation reports, technical reports, and conference presentations (Question 11); and
- Sets budgets and staffing levels that are suited to addressing established goals and priorities (Question 6).

These questions are similar to those asked by RD&T in commissioning several previous TRB reviews. The most recent review, completed in 2015, contained several recommendations about communications, priority

BOX 1-1
Statement of Task

An ad hoc committee will conduct an expert review for the Federal Railroad Administration (FRA) Office of Research and Development (R&D)[a] of the U.S. Department of Transportation (U.S. DOT) to assess its R&D products and services to the agency and railroad industry. The goal of the review will be to provide strategic feedback to the Office of R&D for program improvement and planning purposes with specific emphasis on (1) validating FRA's process to identify new priorities for addressing emerging safety issues and trends, and (2) evaluating the feasibility, usefulness, effectiveness, and impact of R&D products and services in railroad safety. The committee will evaluate each of the four major division areas (Track, Rolling Stock, Train Control and Communications, and Human Factors), including cross division efforts, and R&D support functions (planning, evaluation, and management).

In conducting the review, the committee will consider the following questions:

1. To what extent has the Office of R&D excelled in engaging, maintaining communication with, and using inputs from the full range of stakeholder groups?
2. To what extent does R&D excel in conducting and using results from needs assessments and diagnostic studies to prioritize, focus, and plan projects and programs?
3. To what extent has R&D's planning support function defined a sound mission and associated goals and priorities that reflect assessed safety needs in the railroad industry?
4. To what extent is R&D sufficiently flexible and responsive in addressing changing economic, political, social, and technological contexts?
5. To what extent does R&D's current and planned portfolio and budget appropriately address its defined mission, goals, and priorities?
6. Do the Office of R&D's defined mission and priorities align with its staffing and budget levels?
7. To what extent is the R&D Office's science and engineering work of excellent technical merit and quality, and appropriate and feasible for implementation?
8. To what extent are R&D services and products being, or planned to be used by the railroad industry both internal and external to FRA?
9. How effectively have R&D services and products helped the railroad industry improve safety and reduce fatalities?
10. To what extent does the Office of R&D evaluate its services and products prior to or during an implementation to help improve their usability and likelihood of adoption by industry?
11. To what extent is the Office of R&D effective in providing its key stakeholders with summative evaluation reports, technical reports, conference presentations, and other communications that validly assess R&D efforts, impacts, and cost-benefits?

continued

BOX 1-1 Continued

The committee will deliver two letter reports on its findings and recommendations. The first letter report will include descriptive assessments and actionable comments and advice on the evaluation questions. It will present a holistic assessment of the Office of R&D, the individual divisions, and the R&D support functions. The second letter report will provide an evaluation of the content and delivery of a 2-day, public meeting in which FRA will present its R&D program to stakeholders.

[a] The Office of Research, Development, and Technology is the current name.

setting, strategic planning, and evaluation (National Academies of Sciences, Engineering, and Medicine 2015). Notably that report recommended that RD&T

- Increase its interaction with the engineering, mechanical, operations, and research staffs of the railroads and industry suppliers to improve research dissemination and increase awareness of industry priorities;
- Formalize communication with FRA's Office of Railroad Safety (RRS) on projects of mutual interest and engage with this office to formally evaluate research intended to support safety rulemaking;
- Carry out project selection with the assistance of a software-based decision-support tool and by prioritizing projects that have an implementation partner at a railroad or industry supplier;
- Regularly monitor its progress toward the goals in its strategic plan and use its observations on progress periodically to adjust resources as needed to achieve strategic goals;
- Identify long-term needs in domain knowledge and talent among its personnel and key contractors and implement a plan to meet those needs; and
- Establish evaluation processes for each project, including the use of review panels of external experts.

RD&T's progress in responding to these earlier recommendations was considered as part of this review, which was conducted using the methods discussed next.

APPROACH TO CONDUCTING THE REVIEW

To conduct the review, the National Academies appointed a committee of 14 experts in fields relevant to the study charge, including railroad safety, track and bridge infrastructure, train control and communications, rolling stock, human factors, railroad management and labor, and research program evaluation. As required by the Statement of Task, the 14 members were each assigned to one of four subcommittees charged with conducting more detailed reviews of the work of the four RD&T divisions (see Figure 1-1). The subcommittees reported back to the full committee, which reviewed RD&T's overall support functions. While the subcommittees' work informed the majority of the findings and recommendations in the report, they were all reviewed and accepted by the full committee.

The committee commenced its work by meeting with RD&T's senior management, division chiefs from each of the four research areas, and program managers responsible for specific research projects. These meetings consisted of high-level presentations describing RD&T's mission and goals and strategic planning and other support functions, as well as overviews of the portfolios, budgets, and staffing of the four divisions. During these meetings, the committee reviewed RD&T planning documents, such as the Annual Modal Research Plan (Federal Railroad Administration Office of Research, Development, and Technology 2018b), and queried senior managers, division chiefs, and program managers on project selection and prioritization processes, including their use of decision-support software. The management team was asked to explain how RD&T uses information on safety trends in the railroad industry to inform its program planning, research needs prioritizations, and budget allocations. Managers were also asked to explain how they engage with internal and external interests such as the safety regulators in RRS, other modal administrations within the U.S. Department of Transportation, freight and commuter railroads, railroad labor organizations, and the broader research and technical communities.

The committee also met with officials from RRS, including those having responsibilities specific to the subject matter of the four RD&T divisions. They were asked to explain their research needs and reliance on RD&T products and services. These discussions were deemed important because many of RD&T's products and services are intended to help RRS develop regulations and enforcement tools and methods. In consulting with RRS, the committee recognized the inherent tensions that can exist in an agency that has both regulatory and research responsibilities. It is essential that RD&T be responsive to the agency's need to improve its safety regulations and enforcement tools, while also engaging with industry for information on and insight into safety problems that research can help address. One

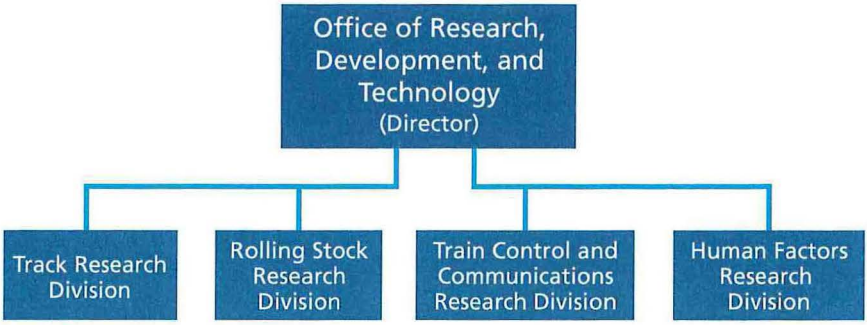

FIGURE 1-1 Organizational chart, RD&T in FRA.

way to facilitate the candid sharing of sensitive safety information is the Railroad Information Sharing Environment, which is under development by RD&T and builds on FRA's existing Confidential Close Call Reporting System. The committee took the view that an intangible benefit of the RD&T program is that it can provide this important nexus of open dialogue for the pursuit of safety improvements.

To conduct their work, the four subcommittees met separately with the leadership and program managers from each of the four divisions. During these in-depth sessions, which included in-person meetings and conference calls, division staff were asked to explain their research priorities, provide an overview of their research portfolios, and offer a more detailed description of a small sample of recent and ongoing projects. Although too few in number to be representative of all of the work of each division, the sampled projects provided the subcommittees with additional insight into the methods used by the divisions to identify needed research, procure projects, and disseminate and communicate results.

To provide insight into how the four divisions set priorities for allocating budget, selecting projects, and managing the two research program areas, the committee asked FRA for data on derailments, their causes, and their severity and then to explain if and how such data are used for budgeting and project programming. The subcommittees then examined the extent to which budget allocations and project selections appear to align with what the incident data suggest are the most significant safety concerns and incident causes. In their review of the data and its presentation in the report, the subcommittees opted against normalizing the frequency data on incident causes (e.g., Chapter 2, Table 2-1), which would typically be an important step in data analysis. They did so for various reasons, including the lack of a clearly appropriate metric with which to normalize, especially one that could be associated with the frequency of any given incident causal factor.

The purpose of requesting incident data was to determine if the research divisions appeared to be focusing their research on the most salient problems. It is important to emphasize that the subcommittees did not try to use the incident data to assess whether the research was successfully solving those problems or leading to increased safety outcomes. The committee was not charged with conducting such research project and program effectiveness evaluations, nor can they be done simply by examining incident data. However, the committee was asked to assess RD&T's means for evaluating the effectiveness of its projects and programs, which are the subject of the study's recommendations.

In addition, the subcommittees consulted a range of railroad industry professionals with backgrounds in freight and commuter railroading, academic and private sector research, and consulting. These professionals were selected from a pool of researchers and industry research partners who had worked on FRA projects and based on suggestions from the Association of American Railroads. Although the interviews were not highly structured or accompanied by a formal questionnaire, these individuals were asked for candid feedback on the quality and relevance of RD&T's research as well as its methods of outreach in identifying research needs and in communicating, disseminating, and evaluating results. The individuals consulted are included in the Preface and in Appendix B.

Following the completion of the subcommittees' reviews, the committee as a whole convened to discuss their findings and recommendations, which are contained in each of the chapters of this report. There was considerable commonality in subcommittee observations and the recommendations that stem from them. This overlap could be expected because the divisions follow many of the same processes for identifying research needs, procuring projects, and disseminating and communicating results.

It merits noting that the Statement of Task calls for the committee to conduct its review in two phases, each producing a short letter report. The first phase was supposed to contain descriptive assessments and advice on the specific questions in the Statement of Task. The second phase was supposed to entail a 2-day, public meeting (or workshop) in which RD&T would present its R&D program to stakeholders, after which the committee would deliver a second letter report that summarizes and assess the discussions from the workshop. In concurrence with RD&T, the study committee chose to forego the plan for a workshop and focus instead on consulting with individual stakeholders in conjunction with the four division reviews. This decision to amend the study work plan, a prerogative of the committee in deciding how best to respond to the substantive elements of the Statement of Task, stemmed from concern that a short letter report could neither adequately describe the content and functioning of the four research divisions nor convey the committee's review. While the summaries

that are provided in this longer report of the feedback from consulted stakeholders is not a substitute for the feedback that could be anticipated from a public workshop, the committee concluded that the planning and organizing needed to design, arrange, and execute a workshop that would be sufficiently insightful—and not an exercise aimed mainly at demonstrating outreach—was beyond its capabilities. However, the importance to RD&T of convening such workshops on a regular basis was recognized by the committee, as conveyed in its recommendations.

REPORT ORGANIZATION

The results of the committee's review are presented in the five chapters that follow. Chapters 2 through 5 examine the work of the four research divisions in some depth. The chapters are organized similarly, starting with a more detailed review of the safety issues and problems relevant to each division—again by reviewing FRA data on incidents and their reported causes. In each case, consideration is given to how research needs are identified and priorities set both on the basis of these data and other inputs, such as by consulting with RRS, industry, and experts from academia and other research institutions. Each chapter contains a synopsis of consultations with external parties, and three to five sampled projects are discussed in most chapters with an eye to how the research topic was identified and selected, how the work was conducted (e.g., any partnering with industry), and how the research results have been, or expect to be, communicated and used in the field. Informed by this review, the subcommittees responsible for each chapter offer observations and recommendations with the concurrence of the full committee.

The report concludes with Chapter 6, which evaluates and provides advice on RD&T's research support functions, focusing on those related to strategic planning, communications, and impact evaluation. The chapter concludes with observations and recommendations pertaining to these support functions, informed by the subcommittees' reviews of the four RD&T divisions.

Appendix A contains data on FRA incident reports from 2015 to 2019. These data are referenced in the individual chapters when considering the extent to which research portfolios reflect safety problems observed in the field. Appendix B lists all meeting dates and study participants. Appendix C includes the biographic information of the committee members.

2

Track and Structures

The Track and Structures Division (Track Division) manages a contracted research portfolio dedicated to reducing the frequency and severity of train derailments. The division seeks to further this objective through three research programs: track and structures, track–train interaction, and testing facilities and equipment. The track and structures program develops and promotes implementation of track inspection technologies, autonomous inspection methods, new techniques for monitoring track safety issues that are difficult to detect, and computer modeling capabilities. The track–train interaction program seeks to improve understanding of derailments arising from the dynamics between the track and the components of the train, including through support for more effective modeling and simulation of vehicle–track interactions. The testing facilities and equipment program administers logistics and maintenance for Federal Railroad Administration (FRA)- and U.S. Department of Transportation (U.S. DOT)-owned resources. This program includes track geometry cars and U.S. DOT's Transportation Technology Center in Pueblo, Colorado, where laboratories, testing equipment, and different types of track and railcars are used for experimentation and analysis. This chapter focuses on the track and structures and the track–train interaction programs, recognizing that these testing facilities and equipment are used to support both research programs.

To provide insight into how the Track Division sets priorities for allocating budget, selecting projects, and managing the two research program areas, the track subcommittee asked FRA to provide data on derailments, their causes, and their severity and then to explain if and how such data are used for budgeting and project programming. The subcommittee then

examined the extent to which budget allocations and project selections appear to align with what the incident data suggest are the most significant safety concerns. The subcommittee then asked the Track Division staff to explain other tools, methods, and criteria used for priority setting and for evaluation of project and program results. To supplement this information, the subcommittee consulted external parties familiar with work of the Track Division, seeking their views on whether the division's priorities align with safety needs and whether research has been effective in meeting these needs. Finally, the subcommittee took a closer look at five recent or current projects in the division's portfolio. In each case, consideration is given to how the project was selected and procured, how the work was conducted (e.g., any partnering with industry), and how the results are used by industry to impact safety.

Based on this review of safety data, information obtained from the discussions with division staff and external parties, and insights gleaned from the sampled projects, this chapter concludes with several observations and a recommendation.

ROLE OF DERAILMENT DATA IN THE IDENTIFICATION OF RESEARCH NEEDS

As a starting point for assessing the Track Division's two research programs, the track subcommittee reviewed FRA data on the incidence and severity of derailments by cause. As discussed previously in Chapter 1, during the 5-year period from 2015 to 2019 an average of 1,300 derailments were reported to FRA annually (see Appendix A, Figure A-1). Of that total about 35 percent, or 450 to 500 per year, were derailments having track-related causes (see Table 2-1). Even more specifically, track component defects were the main track-related cause, occurring about twice as often as derailments caused by track-train interactions (more commonly known as vehicle–track interactions). Examples of track component defect causes are broken rails and insecure switch fasteners. Examples of vehicle–track interaction causes are wide gauge and track misalignment.

Table 2-2 shows the top causes of track-related derailments—that is, the seven causes that accounted for more than half of all these derailments, which include wide gauge and broken rail. However, when considering incident severity based on reportable damage,[1] a different set of causes stand

[1] Reportable damage includes labor costs and all other costs to repair or replace in-kind, damaged on-track equipment, signals, track, track structures, or roadbed. Reportable damage does not include the cost of clearing a wreck; however, additional damage to the above-listed items caused while clearing the wreck is to be included in the damage estimate (Federal Railroad Administration Office of Railroad Safety 2011, 20). The reporting threshold is $10,700 for 2019 (Federal Railroad Administration 2019).

TABLE 2-1 Number of Derailments Resulting from Track-Related Causes, Including Track Component Defects and Vehicle–Track Interactions, Reported to FRA

Derailments	2015	2016	2017	2018	2019
Track component defects	326	309	286	339	296
Vehicle–track interactions	176	187	175	181	173
Total	502	496	461	520	469

NOTE: The committee used its judgment to make a determination of which incident causes could generally be attributed to a program area.
SOURCE: Federal Railroad Administration n.d.b.

out. As shown in Figure 2-1, just four causes—detail fractures (fracturing near the rail head), track alignment irregularities (buckled track), wide gauge associated with defective or missing crossties, and roadbed issues (e.g., defects in the earthen foundation on top of which the ties, rails, and ballast lie)—accounted for more than one-third of total damage. Moreover, more than 70 percent of total damage was attributed to just 14 causes.

Based on these incident data, one might expect the Track Division to place a heavy emphasis on research aimed at reducing the occurrence of these top causes of track-related derailments, especially those track defect causes associated with a large majority of reportable damage. While the Track Division (like other Office of Research, Development, and Technology [RD&T] divisions) does not categorize its program areas by the type of incident causes being addressed, the division chief and program managers explained to the subcommittee that safety data inform project selection. Indeed, assigning incident causes to either of the two program areas can be problematic. They

TABLE 2-2 Five Most Frequent Track-Related Derailment Causes Reported to FRA, 2015–2019

Derailment Causes	Number of Incidents
Wide gauge due to defective or missing crossties	418
Broken rail—Detail fracture from shelling or head check	218
Switch point worn or broken	164
Wide gauge due to defective/missing spikes/other rail fasteners	131
Broken rail—Transverse/compound fissure	100
Broken rail—Vertical split head	98
Roadbed settled or soft	90

SOURCE: Federal Railroad Administration n.d.b.

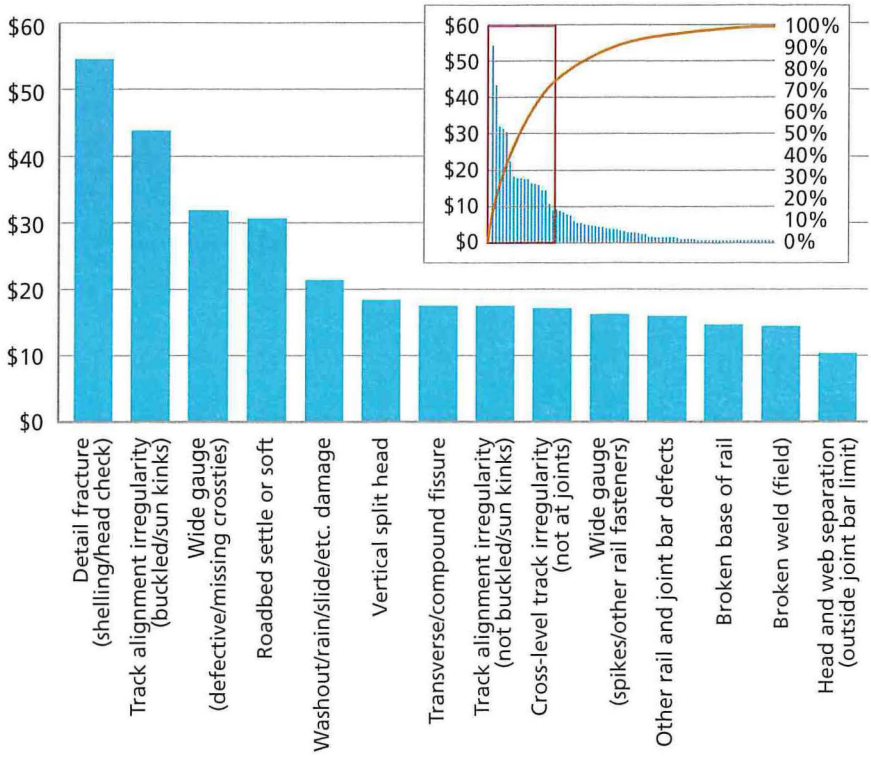

FIGURE 2-1 Track-caused incidents that resulted in damage valued at $10 million or greater and were reported to FRA in millions of dollars from 2015 to 2019.
NOTE: Inset shows all 63 incident causes and how the top 14 account for more than 70 percent of all reported damages.
SOURCE: Federal Railroad Administration 2020b.

reported that the most severe incidents drive the allocation of resources to research projects that are aimed at reducing or eliminating their causes, but they also noted that other factors can be influential as discussed below.

A theme that characterizes many of the Track Division projects is innovation in track inspection capabilities to help reduce the incidence of derailments caused by track defects. Of the 39 active projects in 2019, most involved advanced track inspection technologies that can augment or substitute for inspections conducted by safety personnel. Other projects were intended to provide technical support for enforcement of FRA's track safety standards. Examples include thermal and subsurface imaging to detect defects and machine learning to predict where tracks may fail in the future to better focus inspection resources on managing by prevention.

OTHER CONSIDERATIONS WHEN PROGRAMMING RESEARCH

The Track Division leadership and program managers who briefed the committee explained that the other considerations that go into programming the Track Division's research include an interest in projects that further U.S. DOT's strategic goals, address legislative mandates, and respond to needs identified by other FRA units and industry.

Because the products and services from RD&T support innovations in safety inspections and regulatory techniques, FRA's Office of Railroad Safety (RRS) is considered a key customer. Accordingly, Track Division staff interact with RRS staff through various means. For instance, the Track Division chief and other RD&T division chiefs attend an annual RRS training event to gain a better understanding of safety inspection methods and associated regulatory needs. Indeed, RRS safety regulators pointed to some specific research products coming from the division that have met inspector needs such as machine vision technology for detecting risks associated with rail joints and track geometry inspection techniques for reducing risks of gauge changes from defective crossties and fasteners. Track Division and other RD&T staff hold monthly meetings to discuss research and safety needs. In addition, they join RD&T staff from the other research divisions in meetings of the Railroad Safety Advisory Committee.

The subcommittee was also told that the regular participation by Track Division staff at meetings and conferences on railroad research provides an important means of obtaining information on railroad industry needs and possible research opportunities, such as meetings of the Association of American Railroads (AAR) Research Committee and academic conferences such as the biennial International Crosstie and Fastening System Symposium held at the University of Illinois at Urbana-Champaign, which is supported by RD&T (Federal Railroad Administration Office of Research, Development, and Technology 2019e). Input from industry on research needs is considered important for addressing the right problems and finding solutions that have a greater chance of being adopted. Use of the Broad Agency Announcement (BAA) as an important method of procurement provides a means for the Track Division to engage with researchers from academia and industry to identify research needs and project ideas. In-kind support and other contributions to projects by AAR and individual railroads are considered important for this reason.

Examples of Track Division collaborations with railroads include the development of a vehicle–track interaction monitor and autonomous track geometry measurement system (ATGMS), which is now used widely

by FRA and railroads to monitor track conditions.[2] The Track Division has also partnered with Amtrak to examine wheel–rail interface profiles for passenger rail service.

To assist with project prioritization and decision making, the Track Division, like the other research divisions, had employed portfolio and budget planning software that scores candidate projects for several years. However, the subcommittee learned through discussions with Track Division staff that the use of the program has been suspended while the weighting parameters are updated. Further discussion of this decision-support tool, Decision Lens, can be found in Chapter 6.

PROGRAM BUDGET ALLOCATIONS

The Track Division's annual budget fluctuated slightly from 2015 to 2019 but was generally around $11 million (see Figure 2-2). About 20 percent of that amount was spent on testing facilities and equipment, leaving about $9 million per year to split between the track and structures program and the track–train interaction program. Research conducted by the former program accounts for about two-thirds of the spending. As noted in Table 2-1, track component defects are the predominant cause of track-related derailments, which may explain the larger research sums for research on track and structures. In 2018, the track and structures program funded 26 research projects, compared to 10 by the track–train interaction program (Federal Railroad Administration Office of Research, Development, and Technology 2019a). From 2017 to 2019, the number of projects in the division's total portfolio ranged from 39 to 54, with some projects covering topics that spanned both program areas (Federal Railroad Administration Office of Research, Development, and Technology 2018a, 2019a, 2020a). The full list of current projects in the two programs is provided in Table 2-A1 in the chapter annex.

EXTERNAL VIEWS ON RESEARCH RELEVANCE AND IMPACT

To obtain insight on how others view the relevance and impact of the work of the Track Division, the subcommittee consulted with three researchers from academia and representatives from the AAR industry who had familiarity with the two research programs and their results. (Appendix B includes a list of individuals consulted.) The general response was one

[2] Railroads have implemented 14 ATGMS units in the North American market and 16 units internationally, with both markets presenting opportunities for many additional backlogged and potential orders (Federal Railroad Administration Office of Research, Development, and Technology 2019c, 15).

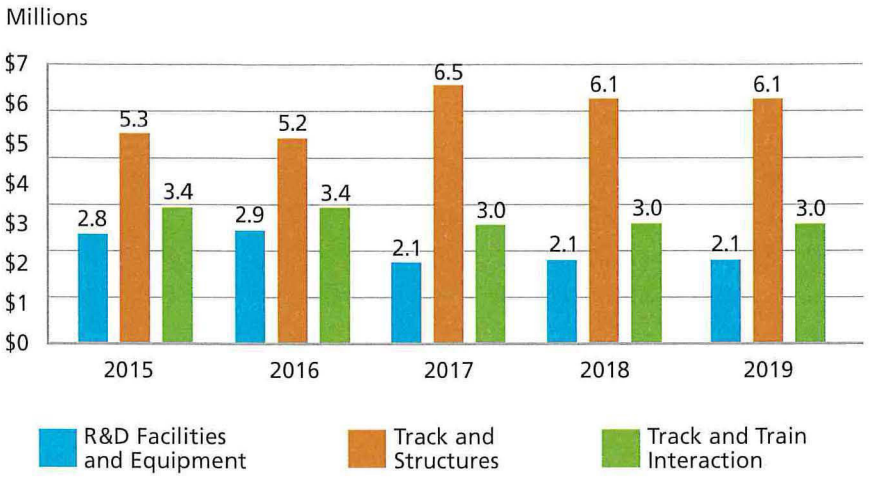

FIGURE 2-2 FRA Track and Structures Research Division budget by major program in millions of dollars.
SOURCE: Federal Railroad Administration Office of Research, Development, and Technology 2019d.

of satisfaction, especially with Track Division staff's technical expertise and understanding of the problems that are the subjects of the contracted research. The researchers favored the division's use of BAAs for programming research, which allowed for more research ideas to be pursued and increased their interaction and communication with Track Division staff. The subcommittee also learned from these consultations that many of the division's projects are collaborations, in which the team performing the work engages with one or more partners from industry. According to the outside experts who were consulted, these partnerships have been valuable for ensuring that the work remains relevant and the result likely to be adopted in the field. Indeed, the previous Transportation Research Board committee that reviewed FRA's R&D program recommended that greater emphasis be placed on such collaboration (National Academies of Sciences, Engineering, and Medicine 2015, 7).

Researchers who had previous experience doing contract research for the division noted that requirements for monthly progress reports by conference call tended to lead to greater clarity of expectations by all parties. The consulted researchers did, however, offer a few ideas on where and how improvements could be made to the program, including on the communications side. One idea was that the Track Division sponsor an annual research conference with industry and RRS staff to discuss project results and new project proposals to further improve the portfolio's alignment with

the needs of industry and safety regulators. Another was for more projects to have longer time horizons (beyond 2 years) so that research teams could involve more doctoral students and thereby expand the talent pool in the field.

INSIGHTS ON PROJECT SELECTION, PROCUREMENT, AND IMPACTS FROM A SAMPLING OF PROJECTS

From a list of active and recently completed projects (see the chapter annex), the subcommittee selected five for further review to ascertain the methods used for project selection and procurement and for more insight into the impact of the track R&D program. Although not selected on a scientific basis, the five sampled projects are helpful for illustrating project selection criteria, procurement methods, and impacts. Project details for the following cases are based on the subcommittee's public data-gathering sessions and RD&T's listing of current projects for 2019 (Federal Railroad Administration Office of Research, Development, and Technology 2019a).

Robust Railway Track Crack Detection System Using Thermal Signatures

This project was prompted by a finding that a broken rail caused the May 2013 derailment of a Metro-North commuter train in Bridgeport, Connecticut, that injured scores of passengers. Investigators learned that the broken rail was observed on standard optical cameras mounted on several Amtrak trains that had passed the derailment location before the incident. These findings led researchers to consider how broken rails might be identified using machine vision (i.e., in real time through automated means) before they lead to incidents. In this project, consideration was given to the use of inexpensive infrared (IR) thermal imaging cameras, which would be more likely to find widespread implementation by industry. Detection of a broken rail by the sensors on a train would trigger an end-of-train device that could apply brakes faster than a human operator.

The ready availability of low-cost IR imaging equipment led the program manager to focus on this sensor technology because of its likelihood of industrywide adoption. A contractor was selected from 23 proposers solicited through U.S. DOT's Small Business Innovation Research program. The project was split into two phases with a total performance period of 24 months with separate awards in 2017 and 2018. The contractor partnered with the Massachusetts Bay Transportation Authority (MBTA) for field trials. A prototype train-mounted platform consisting of an IR camera, low-power microprocessor, GPS, and temperature and humidity sensor was developed in Phase 1 and deployed on MBTA trains to look for rail cracks. The data were used during Phase 2 to make improvements to sensors and

image-processing algorithms. While the phases were conducted as planned, project managers found that the poor optical resolution from the low-cost IR technology would not yield a viable system, and no plans were made for follow-on work.

Investigation of Timber Crosstie Spike Fastener Failures

Spike fastener failures have been identified as an important cause of derailments from FRA incident reports. This is a multiphase project. In the first phase, researchers sought to determine the extent of spike failures in track and to characterize the track conditions where the failures occur by reviewing derailment reports and literature, surveying railroads, and conducting field visits (Federal Railroad Administration Office of Research, Development, and Technology 2019b). During this first phase investigators discovered that spike failures are prevalent under specific track conditions and can pose a significant risk. A preliminary finite element model (FEM) was developed in the second phase of the project to investigate the effect of load direction and magnitude on spike stress.

In the third phase of the project, which was underway when reviewed by the subcommittee, researchers are testing failure hypotheses developed through FEM methods and laboratory and field experimentation to determine the mechanisms of force transfer in fasteners and the effects of fastener stiffness and spike stress. The goal is to improve fastener designs and installation and maintenance practices that prevent spike failures.

A key to the success of this multiphase project—and prioritization given to it for funding—has been the involvement of industry. The project partners are the University of Illinois at Urbana-Champaign and Class I railroads including Norfolk Southern Railway, BNSF Railway, CSX Transportation, Union Pacific Railroad, Canadian National Railway, and the fastener supplier Pandrol. The first two project phases were funded at $300,000, but these funds were leveraged by the in-kind contributions of the industry partners.

Relationship Between Track Geometry Defects and Measured Track Subsurface Conditions

Selected from proposals to a BAA, the aim of this project is to demonstrate the potential of ground penetrating radar (GPR) to quantify track substructure defects (Zarembski et al. 2020). The second phase developed a probability model of occurrence of track geometry defects as a function of key subgrade parameters (e.g., ballast fouling and ballast layer thickness), as measured by GPR. Results showed a statistically significant relationship between high rates of geometry degradation and poor subsurface conditions,

allowing the development of a predictive model for determining the rate of geometry degradation as a function of these measured parameters.

Phase 1 involved a partnership between the University of Delaware Railroad Engineering and Safety Program and the railway maintenance provider Georgetown Rail Equipment Company. The successful results from the first phase, which cost $290,000 and lasted 28 months, attracted additional interest from railroads, prompting the Track Division to fund a second phase. During this second phase, researchers are analyzing the data collected in Phase 1 using machine learning techniques and developing the software to make better use of GPR data for associating track geometry defects with measured subsurface conditions. The second phase, budgeted for $304,000, is due to be completed in September 2021.

Upgrade of Continuous Welded Rail Software

Continuous welded rail software (CWR-SAFE) provides a computational model for determining the buckling probability of continuous welded rail as a function of factors such as maximum rail temperature. The aim of this project was to modernize the CWR-SAFE software program for use on current computer operating systems and mobile devices and to promote FRA and industry use of the application through a secure website. First developed in the 1990s, CWR-SAFE (built on an early Windows platform) was becoming unusable unless upgraded for current technology. Because FRA and the railroad industry use this software to manage the risks from track buckling, the project was prioritized by the Track Division and received in-kind support from railroads.

Funded at $150,000 over a period of 15 months ending in September 2019, the project produced the desired software upgrade and secure website. Although the product is now being used by industry, FRA owns the user rights to the program and has therefore been engaging with industry on options for expanding industry use in ways that do not violate intellectual property rights.

Bridge Condition Assessment Using Smart Sensors

This multiphase project originated from a BAA proposal to develop a sensor-based system for assessing bridge safety by measuring bridge movement under active loading. The measurement data are intended to provide railroads with additional quantitative means for prioritizing bridge maintenance and replacement. First awarded in 2013, the first phase (completed in 2015 at a cost of $164,000) involved a partnership between the University of Illinois at Urbana-Champaign and Canadian National Railway to develop the sensor system hardware. During the second phase (completed

in 2016 for $136,000), data collected from field trials of equipment on multiple bridges were used to establish service limit thresholds and test estimation algorithms and the user interface for the system.

In addition to the initial project partners, multiple short line railroads joined in Phase 3, which studied bridge safety limits based on the assessment system and empirical data for use by railroads in their prioritization of bridge maintenance. Lasting for 29 months and costing $355,000, this project exemplifies how partnerships with industry can be valuable for focusing research on practical problems and ensuring usable results. This project too, however, faces deployment challenges as FRA has user rights while the University of Illinois at Urbana-Champaign owns the intellectual property.

OBSERVATIONS

Informed by derailment causal data, information obtained from the discussions with division staff and external parties, and insights gleaned from the sampled studies, the track subcommittee makes the following observations, which are the basis for advice offered at the end of this chapter.

Value of Safety Data and Industry Collaboration in Project Selection

The budgets for the Track Division's two research programs on track and structures and vehicle–track interaction align with data on track-related derailment causes. About twice as much funding is devoted to the research in the track and structure's program, which would seem to be appropriate because track defects are common causes of derailments and account for about twice as many derailments as train–track interaction causes. Although it would not be possible to map all projects to incident causes, the portfolio contains many projects that are clearly aimed at finding solutions to high-severity incident causes such as detail fractures, track buckling, and wide gauge.

Selections of research topics and proposals are also informed by other means, which were particularly evident from the sample of projects. The Track Division appears to place a heavy emphasis on proposals that involve partnerships and collaborations with railroads, suppliers, RRS staff, and other potential users of the results. According to Track Division staff and the industry and academic researchers who were consulted, such stakeholder engagement and partnering can be particularly important for track-related projects that require field investigations, testing, and deployments.

The subcommittee notes that decision-support tools can be an effective means for developing and articulating the rationale for project selection,

such as the Decision Lens software that had been in use. Renewed use of such software, once recalibrated, should lead to even more effective means for project selection and even more effective communication of research priorities with industry and other audiences, especially if combined with other means such as periodic conferences with industry to discuss the basis for past project selections. Chapter 6 includes a discussion of the use of decision-support tools in project selection.

Reliance on Phased Procurement

The sampled projects also illustrate how the Track Division phases research, often into two or three phases that each have a well-defined set of tasks, timetables, and required outcomes to justify the funding of follow-on phases. The use of separate procurements for distinct phases of larger projects can be an effective means of reducing risk through the establishment of clear checks on project quality. Phased procurement can also enable the funding of more projects with a limited annual budget. Indeed, Track Division staff indicated that heavy reliance on phasing is at least partly attributable to a desire to research more topics with a lean budget.

However, a drawback of such a phased approach is that it can slow progress on low-risk projects that have a higher likelihood of commercial viability. Another drawback is that it can lead to a portfolio with many active projects, which can create administrative challenges for program managers. Phasing can consequently lead to delays in both the conduct of research and the administration of projects that can slow the development and deployment of important safety technologies.

Advance Planning to Assure Widespread Deployment Capability

Evident in the selection of projects and the frequent partnering of research contractors with industry is the Track Division's emphasis on ensuring that research addresses industry needs and has natural avenues for technology transfer through industry partners. The willingness of railroads, suppliers, and others from industry to participate in a project is a clear sign that the research topic is important and the innovations being pursued by the research promise to have application in the field. Ensuring longer-term and more wide-scale deployment of successful innovations from research, however, may require even more front-end technology transfer planning to avoid deployment obstacles.

The sampled projects reveal one such obstacle—the management of user and intellectual property rights. As the sponsor of the research, FRA maintains the right to use the product or service developed through the work. The intellectual property rights, however, may reside with the

research organization. The sampled projects on Bridge Condition Assessment Using Smart Sensors and CWR-SAFE Software Update show how this division can present challenges to facilitating more widespread deployment across industry. These challenges are not new, as track subcommittee members recognize them as long-standing issues that would continue to benefit from more advance planning. In the case of the successful effort to update the CWR-SAFE software, the issue of intellectual property, such as user and data rights, is accompanied by the absence of a third-party developer to regularly maintain the software. Here too, advance planning for such a capability would seem to be desirable.

Program funding, as noted above, has declined since 2015, which may necessitate reasonable adaptations to fiscal constraints on the research portfolio for the division. One approach could be a reduction in the number of active projects funded to ensure that the most high-impact research is conducted with sufficient funding to expedite innovation. The track subcommittee believes that projects meeting certain criteria, such as demonstrable proof of concept and commercial viability, merit consideration for fast-tracking by judiciously reducing the use of phasing on certain projects. It would be crucial that rigorous oversight accompany projects with larger contract awards over longer periods of time.

RECOMMENDATION

Based on the observations made above, the track subcommittee, in concurrence with the full study committee, recommends that the Track Division take the following step in conjunction with other relevant actions recommended in Chapter 6: Ensure that technology transfer planning is sufficiently thorough and anticipatory at the outset of projects to take into account and manage the challenges that can hinder desired levels of deployment of research products and services, including the management of intellectual property such as user and data rights.

ANNEX

TABLE 2A-1 Track Division Projects, 2019

Track Division Project Title
Defect Growth Characterization in Modern Rail Steel
Non-Contact Rail Inspection Prototype (Passive-Only System for High-Speed Rail Inspection)
Robust Railway Track Crack Detection System Using Thermal Signatures
High-Speed Broken Rail Detection
Quantification and Evaluation of Rail Flaw Inspection Practices and Technologies
Rail Neutral Temperature (RNT) and Longitudinal Force Management
Rail Neutral Temperature (RNT) Measurement by Virginia Tech
Rail Neutral Temperature (RNT) Measurement (University of Sheffield)
Upgrade of CWR-SAFE Software
Rail Temperature Prediction
Ballast Waiver Support
Quantification of Track Instabilities Due to Ballast Movement at Special Locations Using Integrated Sensor Networks
Innovative Track Inspection Technologies
Relationship Between Track Geometry Defects and Measured Track Subsurface Conditions
Near Real-Time Processing of Targeted Ground Penetrating Radar (GPR) Data for Ballast Condition
Concrete Tie Design and Performance Research
Automated Frog Repair Technology
Bridge Condition Assessment Using Smart Sensors
Investigation of Timber Crosstie Spike Fastener Failures
Portable Rail Suspension Displacement Monitoring System
Track Geometry Measurement System (TGMS) Evaluations
Steering Traction on Wheel and Rail Damage—Full Scale Testing with RCF Simulator (RCFS)*
Evaluation of Wheel/Rail Contact Mechanics and Dynamics*
Ground Truth Measurement of Track Geometry on FRA Test Track*
Vehicle–Track Interaction Testing, Modeling and Analyses*
Rolling Contact Fatigue (RCF) Qualification*
Track Geometry Measurement System (TGMS) Evaluation Procedures
Coil Spring Characterization and Modeling*
Influence of Track Irregularities on Derailment Safety*

Funding	Project Duration
$697,016	January 8, 2016–June 29, 2019
$561,323	May 2016–May 2019
$300,000	May 2017–May 2019
$299,000	May 2017–May 2019
$449,000	July 2016–May 2019
$524,000	July 2016–December 2019
$141,000	July 2018–July 2020
$150,000	November 2018–November 2019
$150,000	September 2018–September 2019
$39,942	September 2018–December 2019
$404,455	August 2018–July 2019
$322,842	September 2018–August 2020
$112,486	August 2018–April 2019
$289,842	August 2016–December 2018
$378,782	September 2018–August 2019
$1,000,000 annually	June 2011–June 2019
$300,000	March 2016–September 2018
$350,000	January 2017–June 2019
$300,000	April 2018–April 2019
$300,000	December 2016–December 2018
$1,225,151	May 2015–December 2018
$2,176,253	September 2013–October 2019
$300,000	September 2017–February 2019 (Phase II)
$480,000	September 2018–September 2019
$231,000	September 2018–September 2019
$90,000 annually	2017–2020
$800,000	April 2015–March 2019
$700,000	2014–2019
$400,000	June 2018–May 2020

continued

TABLE 2A-1 Continued

Track Division Project Title
Support of FRA Office of Railroad Safety
Modeling of Wheel/Rail Friction Modifier*
Advanced Modeling of Wheel/Rail Friction Phenomena*
Track Geometry and Vehicle Performance*
Adjustable Precision Curved Track Anomaly Test Section*
U.S.–China Railway Technology Exchange
Evaluation of Track Inspection Technology Effectiveness
Artificial Intelligence Aided Track Risk Analysis (AI-TrackRisk)
Moisture-Sensitive Ballast Fouling Measurement Tool
Automated Change Detection Technology for Track Inspection

NOTES: Vehicle–track interaction is a research subject for projects marked with an asterisk (*). Funding level is for FY 2019 unless otherwise specified.
SOURCE: Federal Railroad Administration Office of Research, Development, and Technology 2019a.

Funding	Project Duration
$400,000	June 2018–May 2020
$300,000	September 2017–December 2018
$225,000	March 2017–March 2019
$962,862	September 2016–March 2019
$441,000	October 2018–January 2020
$30,000 (FY 2018)	2012–2019
$124,000	July 2018–May 2019
$345,651	August 2018–August 2020
$468,625	July 2016–January 2019
$345,651	August 2018–August 2020

3

Human Factors

The Human Factors Division's research is organized in two general areas, each consisting of subareas of work. One of the two general areas concerns the human performance of locomotive engineers, train crews, maintenance-of-way workers, and other railroad personnel who can affect the safe operation of trains and the safe condition of track. The other concerns the prevention of grade-crossing incidents, suicides, and trespasser injuries and fatalities. The stated strategic priorities for this work are understanding and managing worker fatigue and distraction; addressing human error through automation and improved human automation interaction; developing, implementing, and evaluating strategies to mitigate trespass and suicide incidents; investigating technologies to improve grade-crossing safety and motorists' behavior at grade crossings; and strengthening the safety and organizational culture of railroad organizations. The division employs several methods to carry out this research, including survey research, human subjects' simulator experiments, technology demonstrations, pilot studies with railroads, and funding support for safety culture assessments and training of small railroads.

This chapter is organized in a manner similar to that of the other chapters that examine the four divisions of the Office of Research, Development, and Technology (RD&T). To provide insight into how the Human Factors Division sets priorities for selecting projects and managing its research program areas, the human factors subcommittee asked the Federal Railroad Administration (FRA) to provide data on train derailments and other incidents and their causes and then to explain if and how the data are used for programming the Human Factors Division's portfolio. The subcommittee

then examined the extent to which project selections and program emphasis areas appear to align with what the incident data suggest are the most significant safety concerns pertaining to human performance. The subcommittee then considered how other methods and criteria are used for setting priorities, including engaging with FRA's Office of Railroad Safety (RRS), academia, and the railroad industry. Several individuals from other FRA units, academia, and industry who are familiar with human factors issues and the work of the division were also consulted to obtain additional views on the quality, relevance, dissemination, and communication of the division's work. Rather than select individual projects to examine, the subcommittee focused on two of the division's largest ongoing investments in a human factors laboratory and a safety institute.

The chapter concludes with several observations and recommendations.

ROLE OF INCIDENT DATA IN THE IDENTIFICATION OF RESEARCH NEEDS

The human factors subcommittee reviewed FRA data on train derailments by reported cause, focusing on those in which human factors were reported to be the major cause. It also examined a second set of data on railroad fatalities, noting the dominance of grade-crossing, suicide, and trespasser incidents in these cases. There is, of course, a major distinction to be made among these two sets of incidents. Train derailments owing to human factors and environmental interactions tend to pertain to the performance of railroad personnel, whereas grade-crossing and trespasser incidents stem mostly from the actions of people not affiliated with the railroad and who are usually the victims. In all cases, however, the consequences can be traced to the behaviors, choices, and actions of people, and therefore research into means to prevent such incidents must have a strong human factors dimension.

Derailment Causes Related to Human Factors

Table 3-1 shows the number of derailments resulting from human factors–related causes from 2015 to 2019. From year to year, this figure fluctuated slightly from a little more than 400 incidents to nearly 500 incidents per year—totaling some 2,250 incidents over the 5-year period. As discussed in Chapter 2, an average of 1,300 derailments were reported to FRA annually during the period (see Appendix A, Figure A-1). Human factors, therefore, are a reported cause of more than one-third of derailments.

Taking a closer look at these causal data, the five main human factors–linked causes for derailments during this period were improperly aligned switches (19 percent of incidents), shoving (or pushing) movements when a human was not present at the lead of the train or cut of cars (8 percent),

TABLE 3-1 Derailments Having Human Factors–Related Causes Reported to FRA, 2015–2019

	2015	2016	2017	2018	2019
Derailments	473	413	427	464	473

SOURCE: Federal Railroad Administration n.d.b.

shoving movements when the human at the lead of the train or cut of cars failed to maintain control (8 percent), movements through a switch that had been previously run through (7 percent), and failure to comply with restricted speeds (7 percent). These five derailment causes—out of a total of 95 reportable human factors causes—accounted for about half of train derailments caused by human factors.

When considering the contribution of human factors–caused derailments to total reportable damage from all derailments, they accounted for slightly less than 30 percent of the total during the 5-year period. As shown in Figure 3-1, the following six causes were responsible for more than 40 percent of the reportable damage from human factors–related derailments: improperly lined switches, trains exceeding the speed outside yard limits, excess buff or slack action affecting train handling, uncontrolled or insufficiently controlled shoving movements, and a catch-all category "other train operation/human factors."

Worker fatigue—from shift work, night work, and irregular schedules—has long been considered to be an important factor in many of the most prevalent and consequential human performance–related causes of derailments, such as excess operating speeds and switch run-throughs. FRA's fatigue research program dates back to the early 1990s and continues to be an area of emphasis today. Table 3A-1 in the annex to this chapter shows the 11 active research projects in the Human Factors Division during 2019. At least four of these projects address fatigue, including studies on the impact of commuting on fatigue for maintenance workers and locomotive and monitoring engineers. Another project involves the development of a website intended to inform railroad personnel about the importance of getting adequate rest, the *Railroaders' Guide to Healthy Sleep* (Federal Railroad Administration n.d.a).

Other projects in the Human Factors Division's portfolio seek to address a broad array of derailments and other incidents associated with human performance through investigations of automated systems and technologies and studies of how advanced technological systems in railroading can affect employee training, job design, and other personnel issues. By way of example, one project is examining how artificial intelligence (AI) systems can compensate for the loss of operator situational awareness by automatically detecting and reporting on the state of railway

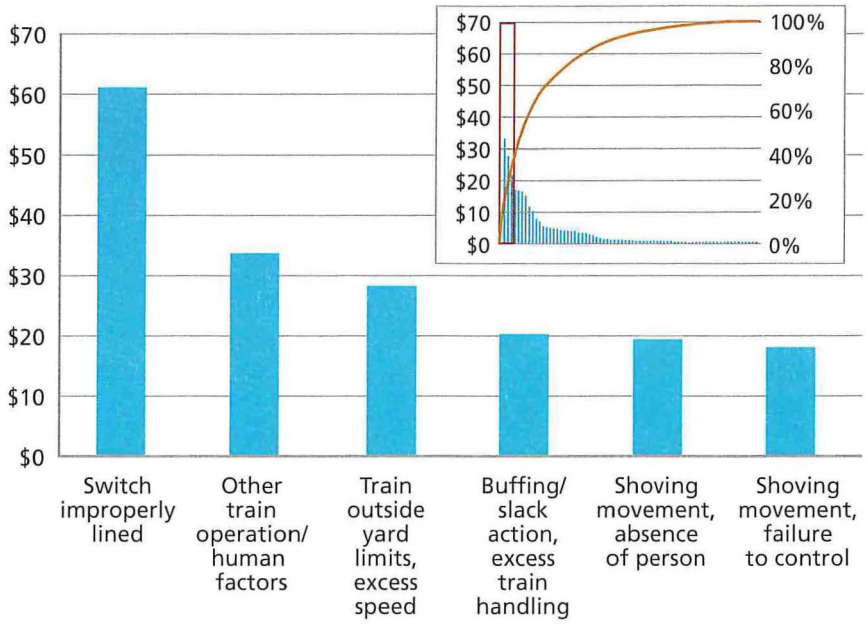

FIGURE 3-1 Human factors–caused derailments from 2015 to 2019 that resulted in damage valued at $18 million or greater and were reported to FRA in millions of dollars.
NOTE: Inset shows all 95 incident causes and how the top 6 account for more than 40 percent of all reported damages.
SOURCE: Federal Railroad Administration 2020b.

signs, signals, and other objects in the path of locomotives. Another project has been investigating a new type of heads-up display that will result in improved engineer/conductor situational awareness of critical events and automation transitions.

To provide a human factors laboratory for much of this work, the Human Factors Division established and funds the Cab Technology Integration Laboratory (CTIL) at the U.S. Department of Transportation's (U.S. DOT's) Volpe National Transportation Systems Center. CTIL is a high-fidelity, full-sized locomotive simulator that serves as a tool for researchers engaged in studies of operator capabilities and performance. To enable the use of CTIL for large projects, the division has been dividing projects into phases, much like the approach used by FRA's other research divisions. Phasing in this manner allows funding to be spread across multiple budget cycles and can provide a checkpoint mechanism to review project progress and modify the research approach if necessary.

The 2015 Transportation Research Board (TRB) review of FRA's R&D program noted that CTIL had been underused and recommended strategic

planning to ensure more effective use of this resource, particularly by communicating its utility to industry to attract more industry interest and collaboration. FRA recently issued a strategic plan that emphasizes the creation of a CTIL research agenda that is informed by an understanding of industry needs and that emphasizes more active communications and marketing with industry.

Fatalities from Suicide, Trespassing, and Grade-Crossing Incidents

Between 2015 and 2019, 5,412 fatalities were reported to FRA from all railroad incidents. Table 3-2 shows the source of these fatalities, the vast majority of which stemmed from trespassing, suicide, and grade-crossing incidents. In nearly all years, trespassers accounted for about 40 to 50 percent of fatalities. Fatalities from grade-crossing incidents fluctuate over the period, but with a slight increase, while suicide fatalities have been declining, with what appears to be a potentially significant decline during 2019. This apparent decline may be attributable, at least in part, to the time it takes railroads and medical examiners to classify grade-crossing and trespasser fatalities as suicides. Grade-crossing and trespassing incidents together accounted for about 80 percent of fatalities in 2019, with some portion of these incidents likely to be reclassified later as suicides.

Of these three major sources of railroad fatalities, suicide prevention currently receives the most attention in the Human Factors Division's research portfolio. In particular, the division supports work by the Volpe Center to identify, implement, and evaluate suicide prevention countermeasures employed by railroads (Volpe National Transportation Systems Center 2017). The work includes using geographic information system mapping technologies to identify locations of trespass "hotspots," understanding the causes of suicides along the right-of-way, investigating whether media

TABLE 3-2 Railroad Fatalities Reported to FRA by Incident Type, 2015–2019

Fatal Incident Type	2015	2016	2017	2018	2019
Grade crossing	237	255	271	260	293
Trespassing	450	467	505	521	578
Suicide	328	274	277	280	206
Other	62	38	42	37	31
Total	1,077	1,034	1,095	1,098	1,108

NOTE: Data for 2018 and 2019 will change contingent on medical examiners' determinations of whether a trespassing or grade-crossing fatality was a suicide.
SOURCE: Federal Railroad Administration 2020a,c.

coverage encourages suicide attempts, and cooperating with railroads and public agencies to disseminate information on the effectiveness of potential countermeasures.

The subcommittee was informed that FRA RD&T funding for grade-crossing and trespasser research is programmed and administered by the Train Control and Communications Division, including projects to ensure safe interaction of road vehicles with trains at grade crossings and the use of AI and machine learning for identifying risky trespasser behavior around railroad tracks and crossings. Given the human dimensions to these issues, the subcommittee was surprised to learn that research in these areas was not programmed with more involvement by the Human Factors Division.

OTHER CONSIDERATIONS WHEN PROGRAMMING RESEARCH

Like the other divisions of RD&T, the Human Factors Division's leadership and staff explained that other considerations go into the programming of the division's research, including U.S. DOT strategic goals, legislative mandates, and needs identified by RRS and industry. A notable example is the division's engagement with industry that led to the creation of the Short Line Safety Institute (SLSI). Spurred by the 2013 tank car unit train disaster in Lac-Mégantic, Quebec, that involved a small railroad, the division began discussions with the American Short Line and Regional Railroad Association (ASLRRA) on the need to improve the safety culture of smaller (Class 2 and 3) freight railroads. These discussions led to a pilot project with ASLRRA, the University of Connecticut, and the Volpe Center to identify ways to measure the safety culture of short line railroads. As a result of this pilot study, and subsequent congressional interest and support, SLSI was created, which now accounts for about 40 percent of the Human Factors Division's budget, as noted below. SLSI uses these funds in part to conduct voluntary safety culture assessments of small railroads using online employee surveys, onsite employee interviews, safety documents reviews, and field observations.

The subcommittee also learned that the Human Factors Division is working with RRS to develop a program similar to the Federal Aviation Administration's Aviation Safety Information Analysis and Sharing program, whereby regulators, airlines, trade associations, labor organizations, and suppliers share safety sensitive data for the purpose of mitigating safety problems. FRA's plan is to develop and pilot a similar program for the railroad industry—the Railroad Information Sharing Environment (RISE)—which builds on FRA's existing Confidential Close Call Reporting System and will require extensive collaboration with the railroad industry. If RISE can be successfully implemented, the division expects it to become

an important source of data for human factors research and to prompt more collaborative research with industry. In addition, it may be considered one pathway for reducing concerns in the railroad industry about joint efforts to improve safety outcomes alongside the research division within its regulatory agency without being penalized for being candid about potential precursors to serious incidents.

PROGRAM BUDGET ALLOCATIONS

As shown in Figure 3-2, the Human Factors Division's budget has been stable over the past 5 years, totaling $5.5 million to $6 million per year, including $2 million to $2.5 million for the SLSI program. Budget breakdowns are not available by the two main areas of research, preventing human factors–related derailments and preventing fatalities from suicides, trespassing, and grade-crossing incidents. The portfolio of recent and current projects in the annex, however, suggests that a large majority of the budget is spent on the former.

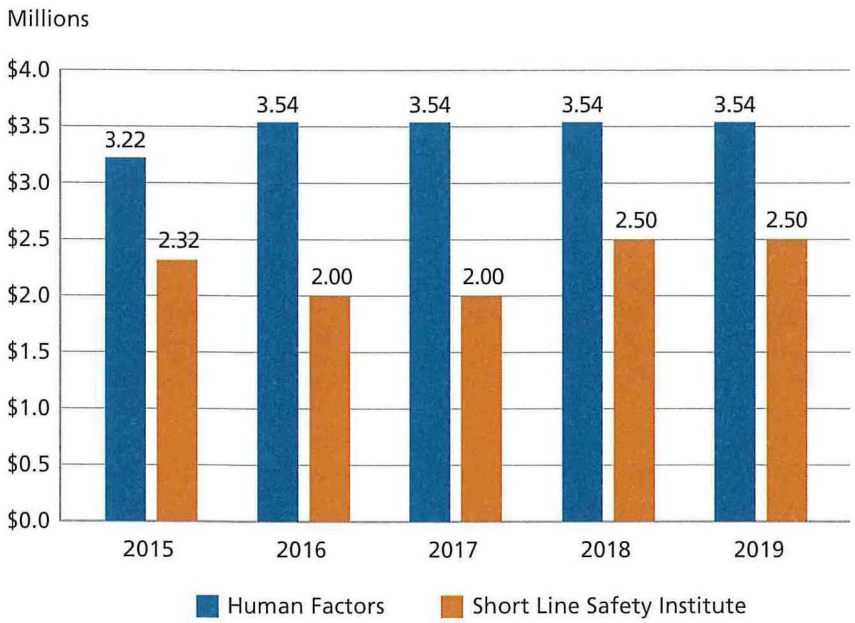

FIGURE 3-2 FRA Human Factors Research Division budget by major program in millions of dollars.
SOURCE: Federal Railroad Administration Office of Research, Development, and Technology 2019d.

EXTERNAL VIEWS ON RESEARCH RELEVANCE AND IMPACT

To obtain insight on how others view the relevance, impact, and reach of the Human Factors Division's work, the subcommittee consulted with researchers who had worked on projects funded by the division, a longtime FRA official from a regional office, and representatives from commuter railroads. The commentary was largely positive, as the work supported by the division was consistently described as high quality, relevant to industry needs, and likely to produce early safety benefits, particularly in the case of suicide and trespassing prevention. Some questioned whether the division's funding levels are sufficient given the importance of human factors research and the cost of investigating automated systems and other technologies. Some also questioned whether the phasing of work into short-duration projects was desirable because it limits the ability of doctoral students, who need longer time commitments, to participate fully in the work. The involvement of such students was described as vital for building human factors research expertise for railroad applications because experience in the field assists in developing a workforce with critical new skills.

The Human Factors Division's research dissemination and outreach efforts were described as competent but still hindered by lags in FRA report review and publication processes. One individual noted that FRA needs to improve its means of notifying industry and other stakeholders in a timely fashion when a research project is complete and the results are available. In particular, FRA's eLibrary was described as being difficult to use to retrieve project reports, prone to technical difficulties, and not always up to date. Several commented that the division's outreach would benefit from greater publicity of pilot test results, expanded use of digital means of communications such as periodic e-newsletters and webinars, and organization of regular dialogue sessions during industry conferences such as those of the American Public Transportation Association. In one conversation, the subcommittee learned that a senior employee of a commuter rail line was unaware of the Human Factors Division or other RD&T divisions and how their research products and services might have benefitted the passenger service. It was pointed out that the implications of the division's work on topics such as suicide and trespasser prevention extend to all railroads and even to the highway sector; therefore, the division should seek out more collaboration opportunities with the Federal Transit Administration (FTA) and the Federal Highway Administration (FHWA), which has closer ties to public agencies that operate heavy- and light-rail systems and state transportation departments that own and operate highways.

OBSERVATIONS

Trespassing and Suicide Countermeasures Program Holds Promise

All indications are that the Human Factors Division's ongoing programs to identify, implement, and evaluate trespassing and suicide prevention countermeasures are coordinated effectively through partnerships with and implementations by railroads. Inasmuch as trespassing and suicide prevention are major concerns for operators of transit rail and highway systems, opportunities may exist for wider application of this knowledge through increased coordination with FTA, FHWA, the public transportation industry, and state transportation departments, as well as with the Train Control and Communications Division, which programs research related to this topic.

CTIL's Strategic Planning Promises More Industry Application and Collaboration

The 2015 TRB review raised concerns that CTIL was being underutilized, especially by industry. The Human Factors Division has since developed its strategic plan for CTIL and placed greater emphasis on industry consultation, collaboration, and communications, which includes holding CTIL stakeholder meetings with industry partners. If implementation continues as planned, this emphasis can help ensure that this world-class human factors laboratory is used to the maximum extent to manage the many ongoing, and in some cases growing, needs to address safety issues such as worker fatigue, the effective application of automation, and improvements in human–technology interfaces and integration.

Phasing Research into Small Projects Has Pros and Cons

The Human Factors Division seeks to maximize the use of funds for research output by staging research projects in phases. One of the advantages of this approach is that it allows funding to be spread across multiple budget cycles and can provide a checkpoint mechanism to monitor project progress and modify research plans as necessary. A disadvantage is that shorter duration projects may not sustain the development of budding human factors researchers, such as doctoral students, whose involvement in projects is needed to build the talent pool for railroad applications. The committee was impressed with the technical knowledge and capability of the division's staff. However, the accumulation and retention of domain knowledge and expertise outside the agency is essential for a research management agency that is dependent on the expertise of contractors.

SLSI Is a Success Story

With a relatively small budget (about $2.5 million per year) provided by the Human Factors Division, the SLSI has provided a needed focus on improving the organizational safety culture of smaller freight railroads. The project illustrates how FRA's collaborations with industry can lead to cooperative solutions to problems and generate support for implementation across the industry. Because there are hundreds of small railroads across the United States, continued funding of SLSI and its safety culture assessments and interventions holds the potential for much wider reach and impact.

Opportunities Remain for Increased Communication and Dissemination of Research Results

The importance of the work conducted by the Human Factors Division does not appear to be matched by its capability to communicate and disseminate the results. Greater use of communication means such as e-newsletters, webinars, presentations, and workshops in conjunction with major industry conferences and technical events would seem to be warranted to ensure that the products of the division's human factors research are known and available to potential users. The wide applicability of much of the division's work in areas such as automation and trespassing and suicide prevention suggests a broader audience may be tapped, including the U.S. rail transit and highway sectors.

RECOMMENDATIONS

Understanding of human factors is important when considering nearly all causes of railroad safety problems and their possible solutions, from the design of safety devices on tank cars and other rolling stock to the development of automated track inspection technologies and train control and communications systems. Insight and knowledge gained from human factors work in the railroad domain can also have broader application to other domains and vice versa. The work and expertise of the Human Factors Division is highly valuable and should be strengthened further and more fully exploited through collaborations with other divisions of RD&T and other modal administrations of U.S. DOT, as well as other agencies that conduct research into human factors such as the Occupational Safety and Health Administration in the U.S. Department of Labor, the Human Factors Program in the Office of Safety and Mission Assurance at the National Aeronautics and Space Administration, and the U.S. Department of Defense Human Factors Engineering Technical Advisory Group. For instance, the division's work that promotes a strong organizational safety culture,

investigates the integration of humans and automated systems, and seeks reductions in trespassing, grade-crossing, and suicide incidents is likely to be of keen interest to FTA and FHWA, both of which oversee transportation modes that have these same needs and interests.

With this goal in mind of expanding the reach and influence of the Human Factors Division, the subcommittee, in concurrence with the full study committee, recommends that RD&T ensure that the Human Factors Division

- Becomes more involved in the design, development, and programming of research projects across FRA's RD&T portfolio; and
- Engages more frequently with other U.S. DOT modal administrations and other relevant federal agencies to identify opportunities for its work to inform, and be informed by, their human factors–related challenges and research, and to collaborate on the design and conduct of relevant research and the dissemination of those research results and products that have broad, multi-modal application.

ANNEX

TABLE 3A-1 Human Factors Division Projects, 2019

Human Factors Division Project Title	Funding	Project Duration
The Impact of Commute Times on the Fatigue and Safety of Locomotive Engineers	$180,000	May 2018–December 2020
New Jersey Transit Run-Through Switch Project	$200,000	October 2016–June 2019
Railroaders' Guide to Healthy Sleep Website www.railroadersleep.org	$600,000	April 2015–March 2020
Maintenance-of-Way (MOW) Worker Fatigue	$150,000	May 2016–June 2019
Head-Up Display (HUD) Alternative for Locomotives	$150,000	June 2016–June 2019
External Perception for Locomotives (ExPL)	$156,000 (PI) $161,000 (PII) $120,000 (PIII)	April 2018–April 2019
Monitoring Engineer Fatigue (MEFA)	$100,567 (PI) $179,580 (PII) $114,471 (PIII)	September 2018–September 2019
Design of a Robust Locomotive Operating Mode	GE 20% cost share $489,304 $500,908	October 2018–September 2020
MIT Augmented Reality Head-Up Display (HUD)	$500,000 $500,000	September 2018–September 2020
Human Error Potential in Human-Automation Interaction	$397,276	September 2018–December 2019
Suicide Countermeasures	$160,000	October 2018–September 2019
Short Line Safety Institute (SLSI)	$2.4 million $100,000 to Volpe	October 2017–September 2018 October 2018–September 2019

NOTES: Funding level is for FY 2019 unless otherwise specified. GE = General Electric; MIT = Massachusetts Institute of Technology.
SOURCE: Federal Railroad Administration Office of Research, Development, and Technology 2019a.

4

Rolling Stock

The Rolling Stock Division's contract research portfolio is dedicated to examining and strengthening the performance and structural integrity of railcars and their components and to developing and improving defect detection technologies. The division seeks to further these outcomes through research on automated inspection technologies and techniques, improved equipment and component materials and designs, train occupant protection enhancements, and improvements to the safety of hazardous materials transportation. An important goal of the division's work is to inform the development of the Federal Railroad Administration (FRA) and industry regulations and standards that apply to rail passenger cars and freight cars, including the development of performance standards for high-speed passenger equipment and railcar suspension systems, and supporting standards for the construction, repair, and maintenance of tank cars. The division employs several methods to carry out this research, including partnering with FRA's Office of Railroad Safety (RRS) and industry on the analysis, development, and testing of materials, detection and inspection technologies, and safety-enhancing designs and devices.

Following the same approach as the other subcommittees, the rolling stock subcommittee queried the leadership and staff of the Rolling Stock Division on the methods used for prioritizing research, allocating budgetary resources, and procuring and managing the research in its portfolio. The subcommittee asked for data on derailments and other incidents associated with rolling stock performance and the specific causes and severity of these incidents. They examined the extent to which budget allocations and project topics appear to align with what the incident data suggest are the most

significant safety concerns. The division's staff was then asked to explain other tools, methods, and criteria used for setting priorities and evaluating research results. To supplement this information, the subcommittee consulted external parties familiar with the division's work and reviewed projects of varying size that span three of the division's main subject areas.

Information and insights gained from the review of incident data, discussions with division staff and external parties, and the sampled projects are summarized next, followed by two general observations and a recommendation.

ROLE OF INCIDENT DATA IN THE IDENTIFICATION OF RESEARCH NEEDS

From 2015 to 2019, an average of 10 to 15 percent of the 1,300 derailments reported to FRA annually (see Appendix A, Figure A-1) were the result of rolling stock–related causes (see Table 4-1). Figure 4-1 shows the top causes of the most consequential rolling stock–related derailments in terms of reportable damage. Four causes of a total of 103 causal codes accounted for 40 percent of reportable damages. Broken wheel rims were by far the leading cause, accounting for about 20 percent of reportable damages from derailments over the 5-year period. The second most frequent cause was overheated journal roller bearings, which accounted for about 10 percent of damage.

Table 4A-1 in the annex to this chapter shows the projects in the Rolling Stock Division's research portfolio at the time of this review (mostly FY 2019 projects). Several projects indeed address wheel, bearing, and other railcar suspension issues, including a wheel failure research program to improve understanding of mechanisms that lead to split and shattered rims as well as projects on wayside detection technologies, understanding the effects of temperature on wheel spalling, wheel temperature detection technologies, preventing water ingress to bearings, wheel life models, and the diagnosis and detection of bearing grease degradation and defects. Other truck components including axles and plates are also the topics of several projects in the division's rolling stock equipment and components (RSEC) portfolio.

TABLE 4-1 Number of Derailments Resulting from Rolling Stock–Related Causes Reported to FRA

	2015	2016	2017	2018	2019
Derailments	166	145	177	175	171

SOURCE: Federal Railroad Administration n.d.b.

Several of these projects, such as research demonstrating the efficacy of advanced wayside detectors, seek to prevent a range of derailment causes. As evident from the list of more than 40 projects in Table 4A-1, the Rolling Stock Division's portfolio extends well beyond wheel and truck issues given the division's large purview over other rolling stock components such as locomotive and car crashworthiness and survivability; train makeup, braking and handling, tank car structural integrity, and safety devices; and locomotive and passenger car fire safety. Accordingly, the projects in the division's portfolio do not always align with specific incident causes associated with rolling stock, because the work is intended to address safety concerns associated with other incident causes, such as research to improve locomotive, passenger car, and tank car crashworthiness. Considerations that go into programming this wide range of research are discussed next.

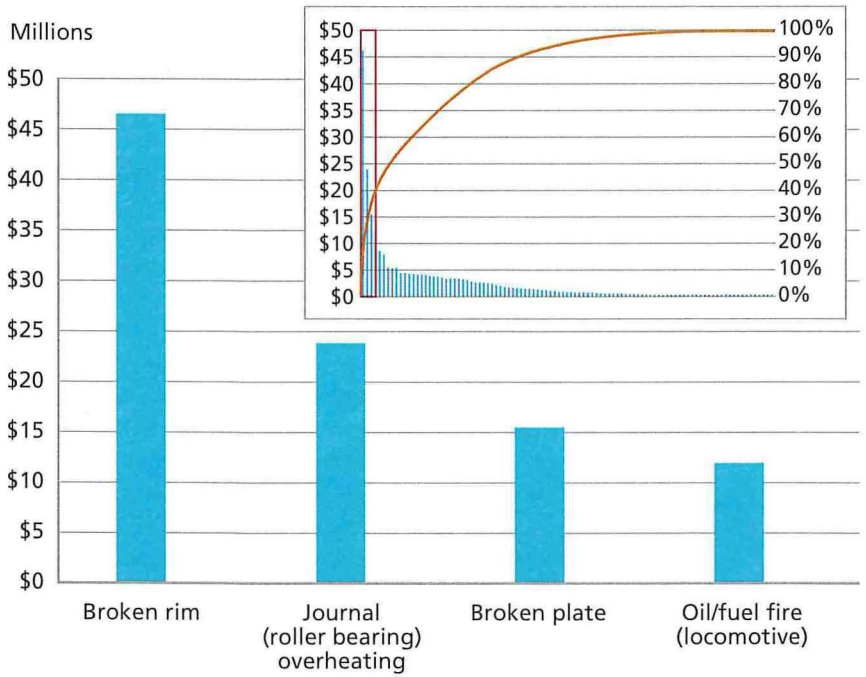

FIGURE 4-1 Rolling stock–caused incidents that resulted in damage valued at $10 million or greater and were reported to FRA in millions of dollars from 2015 to 2019.

NOTE: Inset shows all 103 incident causes and how the top four account for approximately 40 percent of all reported damages.

SOURCE: Federal Railroad Administration 2020b.

OTHER CONSIDERATIONS WHEN PROGRAMMING RESEARCH

The titles of the more than 40 projects in the Rolling Stock Division's portfolio show the breadth of subject matter covered. In addition to aforementioned projects on wheel, truck, and other suspension components, the portfolio contains a large program on tank cars and the safe transportation of energy projects, with some projects underway and others pending. Projects include evaluations of nondestructive means of assessing tank car integrity; assessments of tank car relief devices and other fittings; and full-scale tank car testing. This work has been programmed in part in response to an unprecedented increase in the movement by tank car of flammable liquids such as ethanol and crude oil and the need to ensure the safe containment of these materials following a derailment (National Academies of Sciences, Engineering, and Medicine 2017, 54). The portfolio also aligns with the broader strategic priorities of the U.S. Department of Transportation (U.S. DOT).

Recent interest in the transportation of liquefied natural gas (LNG) by tank car has caused the division to program even more research to tank cars, including research to support the development of new design specifications for cryogenic tank cars. In addition to supporting FRA and Pipeline and Hazardous Materials Safety Administration rulemaking, this work has been prompted in part by congressional mandates and recommendations by the National Transportation Safety Board (NTSB) following investigations of major tank car incidents. In identifying this and other hazardous materials–related research needs, the Office of Research, Development, and Technology (RD&T) has also collaborated with the Association of American Railroads (AAR) Tank Car Committee.

Legislative mandates have long played a role in the programming of the Rolling Stock Division's work, such as in the area of train occupant protection, which has received considerable congressional attention in recent years as a result of fatal intercity passenger and commuter rail train derailments (e.g., in Chatsworth, California; Philadelphia, Pennsylvania; DuPont, Washington; Sparks, Nevada; and Spuyten Duyvil, New York). Here too FRA and NTSB investigations following incidents have factored into the programming of the research, such as projects to develop improved side impact crashworthiness standards.

Through its support for field studies, the Rolling Stock Division also identifies passenger train equipment safety issues—for instance, by documenting the damage to the equipment from derailments and other incidents and identifying causal mechanisms for crew and passenger injuries. Findings from these field studies are used to assess rolling stock research needs in areas such as rail equipment performance, interiors, emergency egress/access, fuel tank integrity, and passenger railcar safety features.

Research demonstrating the efficacy of advanced wayside detectors is an example of work that responds to the needs of FRA's RRS. The Rolling Stock Division is working with RRS to evaluate wayside detection technology implementation plans to enable expedited deployment of technologies that can improve detection of safety-critical defects to increase operational safety and enable railcar owners to make more cost-efficient repairs to their equipment. As one example, the evaluation of these plans is deemed important to inform RRS reviews of requests by freight railroads to travel greater distances before requiring brake inspections.

In alignment with FRA's Annual Modal Research Plan (Federal Railroad Administration Office of Research, Development, and Technology 2018b) and U.S. DOT's RD&T Strategic Plan for FY 2017–2021 (U.S. Department of Transportation 2016) and their emphasis on improving freight mobility, the Rolling Stock Division is conducting an assessment of the operational safety of very long trains. This research focuses on understanding the braking and power distribution requirements and handling needs of such high-capacity trains, including assessments of how these requirements may differ from those of generally accepted practices for train makeup and handling. Enhanced freight mobility is viewed as a potential benefit of this research through the identification of potential risks associated with these trains and the development of suitable mitigation strategies that will enable their increased use.

PROGRAM BUDGET ALLOCATIONS

From FY 2015 to FY 2018, the Rolling Stock Division's budget had been stable, at about $10.3 million per year, although it was down about 10 percent in FY 2019 (see Figure 4-2). Throughout this 5-year period, train occupant protection research has accounted for about 30 to 40 percent of the division's budget, while research on RSEC has accounted for a slightly smaller share (about one-third). The bulk of the division's remaining budget has gone to hazardous materials and tank car safety research.

EXTERNAL VIEWS ON RESEARCH RELEVANCE AND IMPACT

To obtain insight on how others view the relevance, impact, and reach of the Rolling Stock Division's work, the subcommittee consulted with seven individuals from the railroad industry and two university researchers familiar with the division's work.

All seven industry representatives emphasized the importance of regular communication and collaboration with RD&T staff and researchers. They pointed to the Rolling Stock Division's work with industry on fuel tenders and tank cars as good examples of such engagement, which helped inform

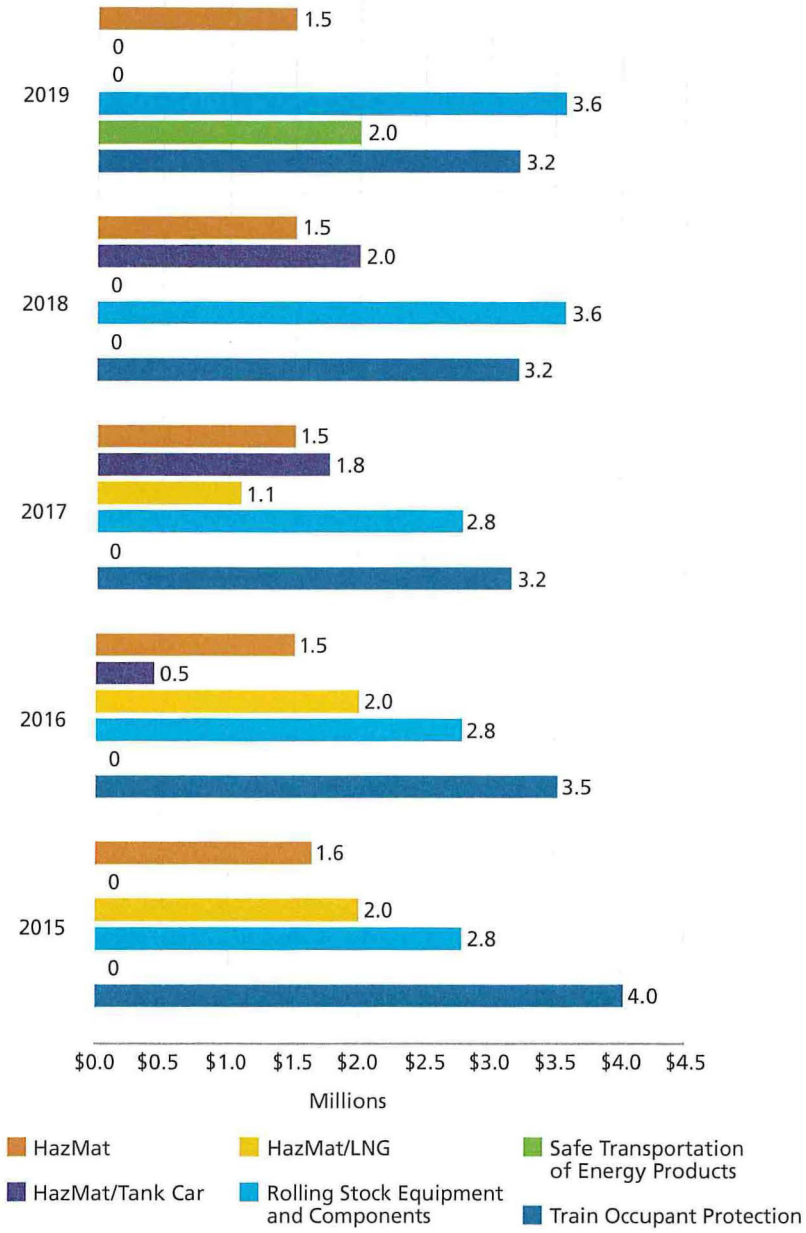

FIGURE 4-2 FRA Rolling Stock Research Division budget by major program in millions of dollars, FY 2015 to FY 2019.
SOURCE: Federal Railroad Administration Office of Research, Development, and Technology 2019d.

the design of the DOT-117 tank car for shipping ethanol and crude oil. At the same time, they expressed interest in even more collaborations of this type. While they noted that Rolling Stock Division staff and researchers attend select industry conferences and other forums where research needs are discussed and results disseminated, they would like to see more participation at railroad equipment–related events. In particular, one commenter noted that while RRS staff usually attend meetings of the AAR equipment engineering committee at U.S. DOT's Transportation Technology Center, RD&T staff are not regular participants. The presence of RD&T staff at this event would provide industry with a more direct line to the research program, while also enabling more open dialogue about research needs than is likely to occur when meeting with only FRA regulatory and RRS enforcement staff.

The Rolling Stock Division's wheel research program was characterized as having made valuable contributions to understanding wheel failure mechanisms. The industry representatives pointed to this work as a notable example of how FRA research can contribute to the knowledge base in ways that can best support industry. They explained that for this very reason—to ensure that RD&T efforts are focused in the most productive manner—consultations with industry are critical. They observed for instance that timely research on wayside detectors can be particularly challenging for FRA to undertake because of the rapid pace of technological development and deployment by industry. It was noted that industry-based innovation and advancement significantly outpaced FRA research efforts. One industry commenter suggested that RD&T's contributions in this area might be better focused on data analytics as opposed to technology development and evaluation.

The two university researchers focused their comments mainly on the project procurement process and ability of the division's portfolio to attract graduate student talent to the rolling stock research field. Although also applicable to the R&D program generally, both researchers commented that FRA's contract-based research tends to specify the direction the research must go, which to some extent negates a strength of academia in working on novel and cutting-edge projects. While recognizing the need for applied research, both researchers proposed that some funds be set aside for mission-specified but higher-risk basic research, offering examples such as machine vision and neural network acoustic analysis for axle roller bearings. One of the researchers commented that the phased approach to project procurement, leading to smaller contracts for shorter performance periods, can be problematic for aligning a graduate student (especially doctoral) research workforce with projects. A multi-year budgeting commitment would strengthen graduate research programs and results.

One researcher expressed an interest in the Rolling Stock Division arranging more opportunities for contractors to engage in regular dialogues

with RD&T and the railroad industry, such as by holding an annual technical review meeting so that researchers have a stronger understanding of industry needs and interests and so that all parties—researchers, RD&T staff, and railroad officials—are aware of ongoing research and recent research products. The researchers questioned the ability of FRA's website repository (eLibrary) alone to meet this need for information and communications.

INSIGHTS ON PROJECT SELECTION, PROCUREMENT, AND IMPACTS FROM A SAMPLING OF PROJECTS

Three Rolling Stock Division research programs are summarized next. They span the three main areas of the division's work: rail equipment and component integrity, train occupant protection, and tank car and hazardous materials transportation. The projects were selected because they illustrate how the division programs research with various considerations in mind, including insight gained from evaluations of incident causal data (wheel failure research), findings and recommendations from incident investigations (passenger equipment crashworthiness), and needs identified by FRA safety regulators (tank car impact tests).

Wheel Failure Research Program

The life of a railroad wheel is determined by various factors. Past research has shown that some wheels can develop high levels of residual tensile stress in the rim that can promote the propagation of radial rim cracks and eventually contribute to catastrophic wheel failures. As noted above, broken rims are the leading cause of wheel-related derailments and the most consequential ones in terms of monetary damage, including those involving unit trains that released flammable liquids. The objective of this program is to increase understanding of current wheel failure mechanisms to aid in the identification of measures to improve wheel performance and reduce derailment risks. Railroad industry partners include AAR and wheel suppliers.

Broken rim wheel failures generally involve a shattered rim or vertical split rim (VSR), with the latter now being more common. Many shattered rim research studies were conducted during the 1990s and early 2000s, including considerable research funded by FRA. The focus of this program is on current failure mechanisms, recognizing that the causes of VSR are not as well understood as the causes of shattered rims. The program involves industry collaboration, whereby an industrywide stakeholder working group evaluates current wheel failure modes and develops research strategies to address them. The research consists of analyses of historical data, testing of failed wheels, and finite element modeling. RRS staff pointed to the Rolling

Stock Division's VSR research as having been particularly important in filling key knowledge gaps needed to improve wheels.

Passenger Equipment Structural Crashworthiness

Following a fatal 2011 accident in which a semi-trailer truck impacted the side of a passenger train traversing a grade crossing, NTSB recommended that FRA develop side impact crashworthiness standards for passenger railcars. Regulatory emphasis has long been placed on maintaining the ability of the passenger railcar to support a large longitudinal load without compromising the space occupied by passengers and crew, as opposed to focusing directly on side structure integrity criteria.

The objective of this project is to investigate side strength requirements for various passenger equipment to develop design strategies for improving the structural crashworthiness of passenger railcars relative to existing designs. Earlier phases examined the current state of side structure integrity, including the makeup of the domestic passenger car fleet, the accident history involving side structures, and side structure design and performance criteria contained in standards and regulations. Modeling is being performed to assess structural performance under a variety of loading conditions and the tendency for rollover when railcars are subjected to side impacts. Another purpose of the research is to assist RRS in assessing waiver requests and evaluating potential changes to passenger car crashworthiness standards.

Tank Car Impact Tests

The division has a longstanding program to evaluate the puncture resistance of existing and candidate tank car designs. The work seeks to develop and validate standardized testing and simulation methodologies for quantifying puncture resistance informed by dynamic crash tests of full-scale tank cars, especially when transporting hazardous materials. The larger objective of the program, funded at about $2.5 million from FY 2015 to FY 2019, is to evaluate the performance of different tank car designs to aid in the improvement of crashworthiness of tank cars. The most recent tests were conducted on a DOT-113 cryogenic tank car, which would be used to transport LNG. The program had earlier tested DOT-105, DOT-111, DOT-112, and DOT-117 tank cars. The tests were conducted at U.S. DOT's Transportation Technology Center by the Volpe Transportation Systems Center and FRA using some tank cars donated by tank car manufacturers and owners.

This program is an example of work intended to inform FRA and industry crashworthiness standards for tank cars, as well as to assist in the improvement of performance-based testing requirements and nondestructive

evaluation methods. In addition to serving these general purposes, the testing serves the specific purpose—in the case of the DOT-113 impact test—of informing an ongoing rulemaking proposal to allow LNG to be transported by railroad tank car.

OBSERVATIONS

Rolling Stock Safety Spans a Wide Domain That Demands Consideration and Balancing of Multiple Interests When Programming Research

While the condition and performance of locomotive and railcar equipment and components can be the cause of incidents, the crashworthiness and other attributes of this rolling stock are critical to lessening the severity of incidents when they occur, regardless of whether the equipment was a causal factor. Thus, while the Rolling Stock Division uses the causal information in the FRA incident database to help guide equipment and component research priorities, research programming decisions are also made with other considerations in mind, such as ensuring that locomotives and railcars protect train crews and passengers and that freight railcars will safely contain their hazardous contents in the event of an incident. This wide purview has led to a large and varied research portfolio that responds to problems identified through examinations of causal factors reported in FRA incident data, legislative mandates, the rulemaking and enforcement requirements of FRA safety regulators, safety concerns identified in FRA and NTSB incident investigations, and other inputs. As a result, the division's portfolio includes more than 40 projects covering topics as diverse as wheel failure research, fire prevention, passenger railcar structural integrity, and tank car impact testing.

Industry Collaboration Is Critical to Ensuring That the Rolling Stock Division's Research Capacity Is Used to Its Greatest Advantage

The Rolling Stock Division's data-driven and industry-partnered research on railcar equipment and components, such as on the failure mechanisms that lead to rims breaking, was lauded by the industry representatives consulted for this review, as was the division's longstanding collaborations with railroads and equipment suppliers to improve the design of tank cars that carry hazardous commodities. However, their comments on the research programmed in some other areas, such as on wayside detection technologies, surfaced concerns about whether the pace of the division's research programming and execution is sufficient to keep up with the rate of technology development and deployment by industry in the field. Consultations with industry during project programming and development are

desirable to better align RD&T's role and strengths with knowledge and technology gaps.

RECOMMENDATION

To better ensure that RD&T projects align not only with the most important safety problems but also focus on research needs that are best suited to the unique strengths of a government contract research program, the Rolling Stock Division should make industry consultations and collaborations a core feature of all research that will ultimately require industry acceptance and application of the results. In having so many diverse research responsibilities, such an alignment and focus is essential to ensuring the effective and judicious use of the division's limited research budget. Moreover, the division should prioritize projects based on safety data; these priorities should be used to determine the number of active projects commensurate with the division's funding level and allocated personnel.

ANNEX

TABLE 4-A1 Rolling Stock Division Projects, 2019

Rolling Stock Division Project Title
Raking Impact Testing of Diesel Multiple Unit (DMU) Fuel Tanks
Load Shedding—Phase III, Concept Development & Prototype
Cost of Compliance for High-Speed Rail Noise
Electronically Controlled Pneumatic (ECP) Brake Device with Pneumatic Emulation—Field Demo
Fire Safety Research
Fire Safety and Emergency Preparedness Research Support
Evaluation of the Structural Integrity of Natural Gas Fuel Storage Equipment for Locomotives
Universal and Inclusive Accessibility for Next Generation of Passenger Rail Equipment
Advanced Devices Train and Test Bed
Advanced Machine Vision of Truck Components
Train Energy and Dynamics Simulator (TEDS)
Risk Reduction for Very Long Trains (VLT)
Wheel Temperature Detector (WTD) Waiver Support
Framework for the Development of Wheel Life Model
Effects of Technology Implementations on Network Operations
Wheel Failure Research Program
Effects of Temperature on Wheel Spalling
Resonant Acoustic Wayside Cracked Axle Detection (RAWCAD)
Diagnosis and Detection of Bearing Grease Degradation and Defects
Technologies and Testing to Prevent Water Ingress to Railroad Bearings
Wayside Advanced Technology Systems (WATS)
Test Rack Hardening of Electrical Power Supply System (EPSS) for Freight Cars
Optimization of Electrically Driven (Set and Release) Hand Brake (EDHB)
Electronically Controlled Pneumatic (ECP) Brakes Implementation and Pilot Demo
Rail Safety Innovations Deserving Exploratory Analysis (IDEA) Program
Non-Destructive Evaluation in Lieu of Hydrostatic Testing of DOT Specification Tank Cars
Non-Destructive Testing (NDT) of Tank Cars and Probability of Detection (POD)
Non-Destructive Evaluation (NDE) of Railroad Tank Cars
Tank Car Impact Tests

Funding	Project Duration
TBD	September 2017–March 2019
$65,700	July 2017–June 2019
$260,000	September 2018–July 2019
$43,500	March 2017–March 2019
$423,000	September 2018–September 2019
$75,000	September 2018–September 2019
TBD	May 2013–April 2020
TBD	TBD
$224,000 (total)	July 2014–July 2019
$530,927 (total)	September 2015–September 2018
$140,000 (total)	September 2015–September 2020
$257,000	July 2017–June 2021
$140,000	August 2017–July 2022
$149,800	September 2018–March 2020
$149,000	September 2018–September 2021
$500,000	September 2017–March 2019
$279,350	August 2017–April 2019
$343,820 (total)	September 2018–July 2021
$100,000	September 2018–June 2020
$150,000	September 2018–November 2019
$89,850	September 2018–September 2021
$299,000	September 2016–September 2020
$348,000	April 2014–September 2019
$98,900	July 2017–June 2021
$400,000	January 2019–June 2021
TBD	Operational in FY 2002 through FY 2018 (Cf., in 2015, small tank car shop non-destructive testing: $100,000)
TBD	(Previously, operational for 2013–2017)
$100,000	October 2018–September 2020
$2,522,063	July 2015–July 2019

continued

TABLE 4-A1 Continued

Rolling Stock Division Project Title
Structural Crashworthiness of Tender for Liquefied Natural Gas
Tank Car Research
Structural Behavior Under Operating Conditions
Structural Behavior under Accident Conditions
Improving Safety of Tank Car Fittings in Hazardous Materials (Hazmat) Service
Performance of Pressure Relief Devices (PRDs) Under Fire Conditions
Fire Performance of a Cryogenic ISO UN-T75 Tank
Full-Scale Tank Car Testing
Passenger Equipment Structural Crashworthiness
Resilient Wayside Structures and Passenger Car Survivability
Locomotive Structural Crashworthiness
Interior Occupant Protection
Field Investigations
Passenger Equipment Glazing Integrity
Aerodynamic Assessment and Design Guidance Manual for High-Speed Rail (HSR)
Improving Survivability for Locomotive Crews
Regulatory Development, Waiver Support, and Technology Transfer

NOTE: Funding level is for FY 2019 unless otherwise specified.
SOURCE: Federal Railroad Administration Office of Research, Development, and Technology 2019a.

Funding	Project Duration
$441,000	August 2017–August 2019
$310,000	September 2018–September 2020
$150,000	August 2018–April 2020
$150,000	August 2018–April 2020
TBD	2016–2020 (previously funded at $150,000 in FY 2018)
TBD	2018–2020
$230,000	September 2017–September 2019
TBD	August 2013–December 2015
$0	August 2018–April 2020 (last funded in FY 2017 at $25,000)
$0	July 2018–January 2020
$1,000,000	August 2018–April 2020
$250,000	August 2018–April 2020
$0	August 2018–April 2020
$137,000	August 2018–April 2020
$73,400	June 2017–March 2019
$378,000	August 2013–May 2020
$0	August 2018–April 2020

5

Train Control and Communications

The Train Control and Communications (TCC) Division consists of two major research programs on train control and communications and trespasser and highway–rail grade-crossing safety. In conjunction with this work, the division sponsors projects on modeling and simulation, automation, and intelligent transportation systems (ITS). In general, the division's research focuses on reducing train collisions with other trains and with people and objects at grade crossings and other railroad rights-of-way.

The largest TCC Division program, train control and communications, focuses on furthering the ability of train operations to make more effective use of information and communications technology to improve safety and railroad network efficiencies. This work includes investigations of levels of train automation to aid in the identification of future automation requirements and standards. Another major area of emphasis is on data collection and analysis tools for monitoring the performance of positive train control (PTC) systems. The division also advances automation, communications, and sensor technologies to enhance PTC.

As noted in Chapter 3, the TCC Division shares responsibility for grade-crossing and trespasser safety research with the Human Factors Division. A focus of the TCC Division's research is on investigating whether and how ITS, including connected vehicle technologies, can help ensure safer interactions of passenger cars, buses, and trucks with trains at grade crossings. The program is also studying how machine learning can help identify risky trespasser behaviors and how the use of technologies such as LiDAR (i.e., laser imaging, detection, and ranging) and drones can help detect and prevent trespassing.

To review the TCC Division's work, the train control and communications subcommittee followed a methodology similar to that of the other subcommittees. First, the subcommittee reviewed relevant incident data, their causes and severity, and whether insights gleaned from such safety data seem to inform project programming and budget allocations. The subcommittee then sought information about other methods and criteria used by the division to identify and prioritize candidate research topics and projects. Additional insights into project selection, relevance, and impacts were obtained from consultations with external parties familiar with work of the division. Finally, the subcommittee reviewed three projects in the division's portfolio for concrete examples of how research sponsored by the division addresses real safety needs and problems.

Based on this review of safety data, information obtained from the discussions with division staff and external parties, and insights from the sampled projects, the chapter concludes with two observations and a recommendation.

ROLE OF INCIDENT DATA IN THE IDENTIFICATION OF RESEARCH NEEDS

To begin assessing the TCC Division's two research programs, the train control and communications subcommittee reviewed the Federal Railroad Administration (FRA) data on the frequency and severity of derailments in which the cause was reported to involve a train control or communications factor. Of the 1,300 derailments averaged per year from 2015 to 2019 (see Appendix A, Figure A-1), about 25 (or 2 percent) were derailments caused by train control and communications factors (see Table 5-1). The most common causes, and also the causes leading to the reportable damage, were automatic control system failures in classification yards (including software, switch, and retarder failures) and power switch failures.[1] These causes account for nearly 80 percent of the damage reported from derailments associated with train control and communications factors from 2015 to 2019 (see Figure 5-1).

TABLE 5-1 Number of Derailments Resulting from Train Control and Communications–Related Causes Reported to FRA

	2015	2016	2017	2018	2019
Derailments	31	22	22	25	17

SOURCE: Federal Railroad Administration n.d.b.

[1] A classification yard is where rolling stock are assembled into freight trains (i.e., switching). A retarder is a braking device adjacent to the rail installed in a classification yard that reduces the speed of freight cars for switching.

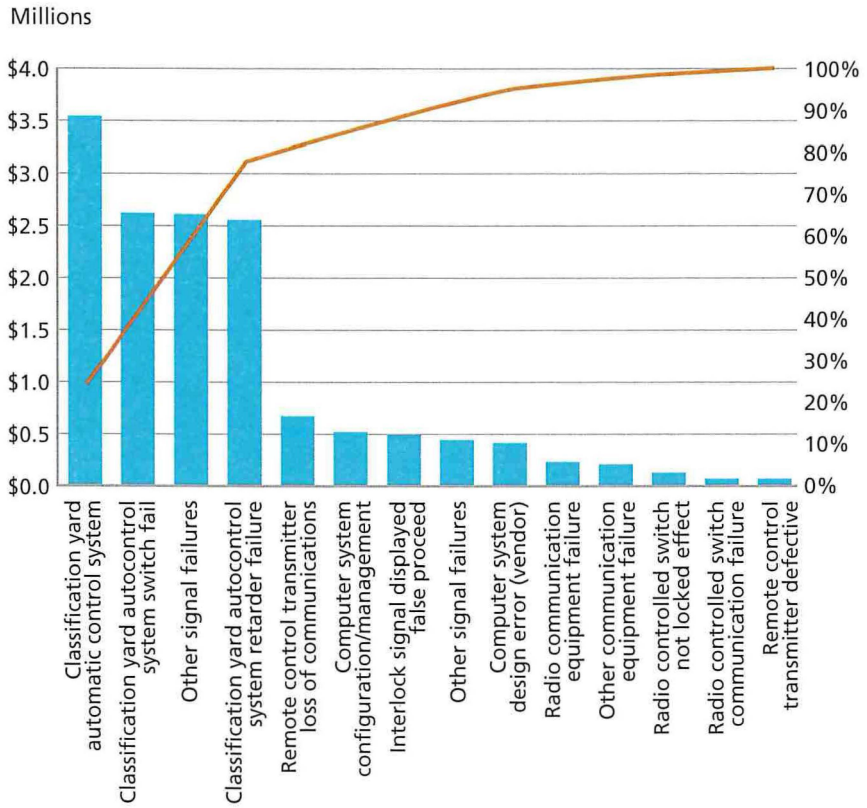

FIGURE 5-1 FRA-reportable damage from incidents caused by train control and communications–related factors, 2015 to 2019.
SOURCE: Federal Railroad Administration 2020b.

As shown in Table 5A-1 in the chapter's annex, the TCC Division's portfolio consisted of about 25 projects during 2018 and 2019. Several projects pertain to automated train operation, largely in the context of PTC assessments. PTC-related projects include track circuit and positive train location research, as well as next generation PTC capabilities such as the advancement of quasi- and full-moving block signaling that would allow trains to run closer together while maintaining required safety margins. Because PTC systems are mandated by Congress to enhance railroad safety, one of the goals of this research is to decrease some of the operational disadvantages of PTC such as reducing message communications failures, overly conservative braking algorithms, and GPS issues that stop or slow trains prematurely or unnecessarily.

The TCC Division's research on grade crossings and trespassing is more readily linked to railroad incident data. As discussed in Chapter 3, trespassing and grade-crossing incidents caused more than 70 percent of all railroad fatalities from 2015 to 2019 (also see Appendix A, Figure A-2). Table 5-2 provides a more complete count of grade-crossing incidents, including both fatalities and injuries.

Human factors, as shown in Figure 5-1, are associated with the most consequential grade-crossing incidents as measured by reportable damage. (High damage incidents tend to involve deaths and injuries.) Driver inattentiveness and misjudgment when crossing the track as well as purposeful disregard of crossing warning signs, signals, and gates are the main causes of the most consequential incidents (see Figure 5-2).

Grade-crossing research is prominent in the TCC Division's portfolio, addressing these human factors causes of incidents. For instance, projects on in-pavement grade-crossing lights, enhanced emergency signage, and connected vehicle–crossing warning systems are aimed at reducing incidents caused by driver inattentiveness and misjudgment. Other work in areas such as incursion prevention systems and on gate skirt research also seek to reduce deliberate crossing violations. The division's research on grade crossings is also accompanied by projects to detect, deter, and reduce trespassing through means such as elevated grade crossings, law enforcement techniques, and drone surveillance.

OTHER CONSIDERATIONS WHEN PROGRAMMING RESEARCH

After a train-to-train collision in Chatsworth, California, the National Transportation Safety Board issued a recommendation for railroads to implement the use of PTC to reduce or eliminate a range of potential incidents caused by human error (National Transportation Safety Board 2008). Congress subsequently mandated the use of this technology on all Class I railroad main lines that transport poison- or toxic-by-inhalation hazardous materials and any main lines with regularly scheduled intercity or commuter rail passenger service. The PTC mandate represents a marked

TABLE 5-2 Grade-Crossing Fatalities, Injuries, and Reported Incidents, 2015–2019

Incident Type	2015	2016	2017	2018	2019
Fatalities	237	255	271	260	293
Injuries	1,048	853	846	845	805
Incidents	1,784	1,739	1,842	1,883	1,920

SOURCE: Federal Railroad Administration 2020a.

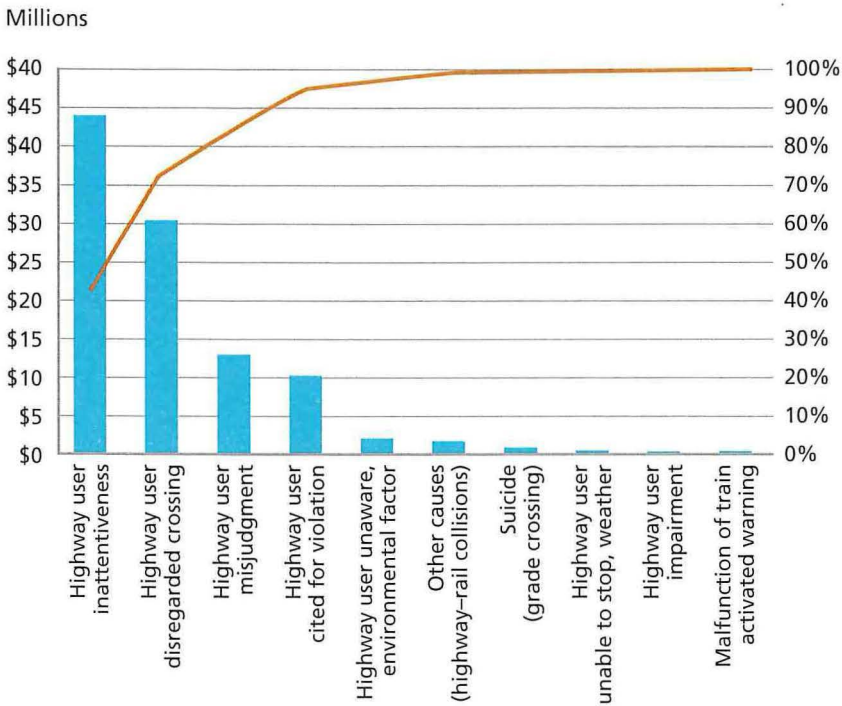

FIGURE 5-2 FRA-reportable damage from incidents at highway–rail grade crossings, 2015 to 2019.
SOURCE: Federal Railroad Administration 2020b.

difference from the other FRA Office of Research, Development, and Technology (RD&T) divisions in that it establishes a long-term research priority for the TCC Division.

Thus, in addition to using incident data to inform project selection, as evident in the grade-crossing portfolio, the TCC Division engages in extensive discussions with the railroad industry on issues associated with implementing and operating PTC systems. Division staff reported that they consult regularly with the Association of American Railroad's (AAR's) Train Control, Communications, and Operations (TCCO) Committee on PTC technical and operational issues as well as other issues. The TCCO Committee convenes monthly by conference call and at several in-person meetings annually to discuss implementation of PTC, and the RD&T staff regularly attend those calls and meetings. Through these interactions, the TCC Division obtains industry input on and support for its research. Indeed, the TCCO Committee has created a consensus-based, priority-ranked

research program list through 2030 that it updates and submits to the TCC Division annually (Newcomb 2020).

TCC Division staff report that its grade-crossing research portfolio is informed by the results of a workshop sponsored by the division every 3 or 4 years. The workshop, which includes representatives from Operation Lifesaver, state departments of transportation, municipalities, railroads, engineering and supplier firms, and academia, typically yields dozens of ideas for research projects (Harrison and DaSilva 2019).

The committee was not apprised of any formal collaboration with FRA's Office of Railroad Safety or its regional offices in planning PTC-related case study projects.

PROGRAM BUDGET ALLOCATIONS

The TCC Division's budget has maintained a funding level of approximately $8 million per year from 2015 through 2019 (see Figure 5-3). During this period, the division has generally allocated the funding between the two major programs such that 80 percent is for work on train control and communications and 20 percent on grade-crossing and trespassing research.

EXTERNAL VIEWS ON RESEARCH RELEVANCE AND IMPACT

The train control and communications subcommittee consulted members of the AAR TCCO Committee asking them about the relevance and impact of the TCC Division's work. The nine members consulted included individuals from AAR, the American Public Transportation Association, and each of the seven Class I railroads. The members were unanimous in expressing their satisfaction about the relevance and quality of the division's research. The general sentiment is that the division collaborates effectively with industry and that the research program continues to produce results having high technical quality and potential to improve safety. The relevance of the work was attributed in part to awareness of the mandate for the train control and communications program to focus on PTC, prompting the industry to submit requests for projects that are needed and that align with this focus.

By and large, the TCC staff were described as subject matter experts who are involved, engaged, and effective in communication. None of the individuals consulted expressed concern over the program's funding levels, expressing satisfaction that the division has been able to leverage its investment by involving the railroads and industry suppliers. Some TCCO members, however, did express concern about lags in the research publication process that could slow the application of useful results in the field, which relies on quickly evolving technologies. They recommended that report

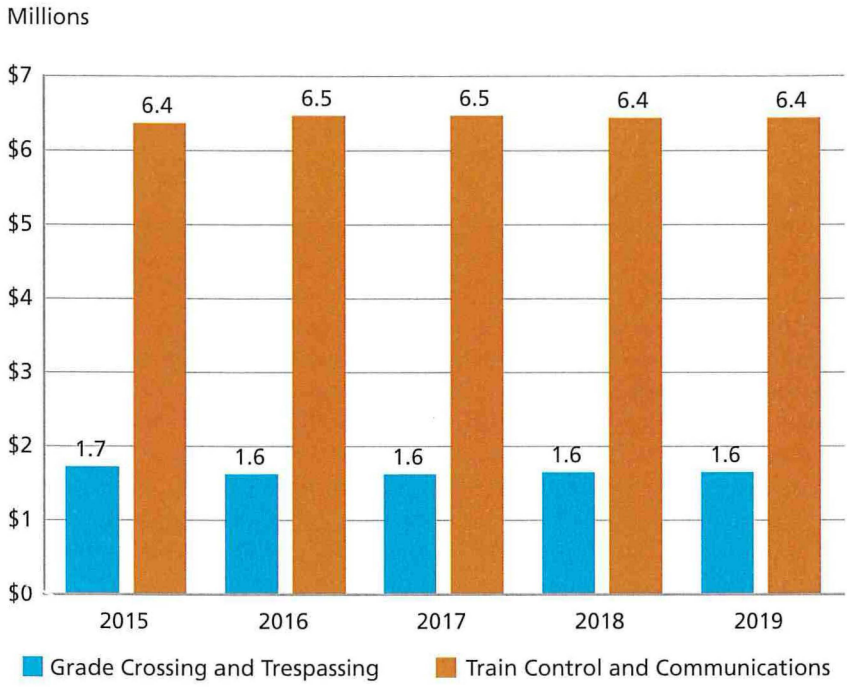

FIGURE 5-3 FRA TCC Research Division budget by major program, 2015 to 2019. SOURCE: Federal Railroad Administration Office of Research, Development, and Technology 2019d.

summaries be made available in advance of a technical report's publication and that interim reports could precede the release of a final report, when practical.

SAMPLED PROJECTS

Three projects from the TCC Division's programs—one from the train control and communications portfolio (on quasi-moving block train control) and two from the grade-crossing portfolio (using connected vehicle technologies for grade-crossing warnings and LiDAR for identifying crossing locations)—were sampled for further insight into how projects were selected and their expected impact.

Quasi-Moving Block Train Control

Railroads have traditionally used circuits that detect trains to divide the track into signal blocks for ensuring the separation of the leading and

succeeding trains. However, because the blocks' sizes are usually fixed and determined by worst-case scenarios and safe braking margins, they can reduce track throughput. The quasi-moving block is a concept that breaks the dependency on track circuits for train detection and replaces it with virtual end of train location. Long fixed blocks are replaced by detection of the actual position of the rear of the train, reducing excessive train spacing and thus increasing capacity.

This project, with a first phase funded at $400,000, seeks to develop a concept of operations, with industry input and review, describing the technical approach for implementing quasi-moving block train control and to analyze communications, hardware, and software needs and identify potential technology gaps. The project is being performed in collaboration with the AAR Interoperable Train Control Committee as a way to increase capacity on rail lines equipped with Interoperable Electronic Train Management System–type PTC. Industry has interest in this work as a means of increasing capacity over the current implementation of PTC and ultimately to yield savings from the future elimination of wayside signals. These savings could be substantial for future train control systems. At the time of this review, the first phase report was awaiting publication.

Grade-Crossing Violation Warning

This project is investigating the use of an interface to connected vehicles that alerts highway users of imminent violation of a grade-crossing protection system. Once a crossing activation has occurred, messages will be transmitted to vehicles in the vicinity of the crossing to alert the drivers, and, if necessary, cause the motor vehicles to stop short of the intersection. The goals of the project are to propose a reference system for in-vehicle driver warning, evaluate the technical feasibility of implementing the proposed system, and make recommendations on future data and analysis needs. Research has applied a systems engineering methodology to design, develop, test, and evaluate a prototype application, and demonstrated the potential for leveraging real-time connected vehicle concepts and services to enhance and transform rail crossing safety.

Initially funded by the Federal Highway Administration (FHWA), the project is an example of an effort to leverage the latest developments in connected vehicle components and technologies developed by past U.S. Department of Transportation (U.S. DOT) connected vehicle deployment projects. The project has involved coordination and collaboration with Honda R&D Americas; the Transportation Technology Center, Inc.; FHWA; the Federal Transit Administration; and the Federal Motor Carrier Safety Administration (FMCSA).

Enhanced Humped Crossing Database Using LiDAR

Highway–rail crossings are continually changing owing to roadway and railway improvements and because the surface approaching the railway crossing will change over time. Of particular interest is the profile of the roadway out of concern that highway vehicles may become struck on the track. The American Association of State Highway and Transportation Officials recommends that the surface of the highway be not more than 3 inches higher or lower within 30 feet of the top of the nearest rail. Apart from this guidance, however, there is currently no formula or threshold for determining if a highway–rail grade crossing presents a risk for low-ground clearance vehicles. Because the actual risk for vehicles to become stuck on tracks has more to do with the rate of change in the roadway grade than its magnitude, accurate three-dimensional models of crossings are needed to properly assess the risk.

This project is investigating a LiDAR-based solution to measure all approach profiles to grade crossings. LiDAR equipment installed on a railcar, such as a track geometry car, collects surface profile data at and around the grade crossing for post-processing. Should the system identify a profile that could cause a vehicle to become stuck while traversing the crossing, an alarm would be generated to alert the railroad and approaching vehicles to protect the crossing until repairs are made. The data collected will also enhance FRA's inventory of highway–rail crossings. To date, nearly 8,000 crossings have been surveyed by the system. Moreover, because the system runs on a continuous basis, it collects data for the entire railway surveyed, which may have other valuable applications such as for asset management, object recognition, and signal sighting.

OBSERVATIONS

The TCC Division's Work to Improve the Operational Capabilities and Performance of PTC Aligns with Its Safety Mission

The TCC Division's major emphasis on PTC is responsive to the public interest of furthering the use of this safety technology and railroad interests in expanding the operational capacity-enhancing benefits of PTC while reducing deployment costs and any operational disadvantages. In recognizing the importance of efficient, precise, and reliable PTC operations to achieving the safety promise of these systems, the division has forged strong connections with the railroad industry to identify and articulate critical PTC-related issues requiring research and industry involvement in projects. While the legislative mandate for PTC deployment underpins this

collaboration, it appears to have promoted collaboration across the division's train control and communications portfolio.

The TCC Division's Focus on Automation, ITS, Communications, and Sensor Technology Recognizes the Importance of Human Factors to Train Operations and Grade-Crossing Safety

Having such a wide breadth of responsibility—from furthering PTC to grade-crossing safety—the TCC Division has demonstrated creativity in harnessing advanced communications, sensors, ITS, and automation technologies to address human performance and behavior issues that can affect safety. Collaborations with other U.S. DOT agencies, such as FHWA and FMCSA, on using connected vehicle technologies to alert drivers to grade crossings exemplify this creativity. While the PTC mandate drives much of the division's research and accounts for a large portion of its budget, the technical capacity and knowledge gained from this work is being leveraged to address other safety concerns and challenges.

RECOMMENDATION

While all of the RD&T divisions face obstacles to getting the results of their research published and disseminated, overcoming these obstacles is especially important for ensuring the timely application of the TCC Division's technology-oriented work. To this end, the TCC Division should make a concerted effort to ensure that research results are made available to industry and other users as quickly as possible to contribute to the advancement of PTC and other systems being deployed in the field.

ANNEX

TABLE 5A-1 TCC Division Projects, 2019

TCC Division Project Title	Funding	Project Duration
Rail Software-Defined Radio (SDR)	$518,188	August 2016–December 2018
Quasi-Moving Block Train Control	$400,013	September 2017–September 2019
Flexible Operator Location Feasibility Analysis	$1,105,414	September 2015–December 2020
Rail Crossing Violation Warning	$853,156	September 2015–March 2020
Positive Train Control (PTC) Critical Asset Track Data Auditing System	$946,641 (total)	September 2015–January 2019
Higher Reliability and Capacity Train Control	$757,951	September 2017–September 2019
Restricted Speed Enforcement for Positive Train Control (PTC) Systems	$400,550	February 2017–May 2020
Pilot Grant Program—Law Enforcement Strategies for Reducing Trespassing	$196,357	October 2018–December 2019
Enhanced Humped Crossing Database Using LiDAR	$299,804	October 2018–April 2020
Cybersecurity Risk Management for Connected Railroads	$799,713	September 2017–November 2019
Trespass Detection and Warning–Drone System	$150,000	January 2018–December 2019
Photo Enforcement-Based Education at Crossings	$250,000	March 2016–June 2019
Gate Skirts Research	$50,000	May 2017–September 2019
Vehicle Railroad Right-of-Way (ROW) Incursion Prevention	$165,000	October 2016–March 2019
Vehicle Blocked Crossing Research	$150,000	March 2017–June 2019
Rail Right-of-Way (ROW) Trespass Mitigation Treatments	$300,000	October 2014–September 2019
LED-Enhanced "Do Not Stop on Tracks" Sign Research	$185,000	June 2017–June 2019
Emergency Notification System (ENS) Sign Study	$150,000	June 2018–November 2019
National Trespass Workshop	$150,000	January 2019–December 2019
In-Pavement Grade-Crossing Lights	$190,000	September 2016–September 2018

continued

TABLE 5A-1 Continued

TCC Division Project Title	Funding	Project Duration
Effect of Grade Separation on Trespassing	$175,000	October 2014–September 2018
Grade-Crossing and Trespass Research Program Support	$210,000	November 2016–March 2019
Positive Train Control (PTC) Interoperability	$886,000 (total)	March 2017–March 2020
Monitoring and Analysis of the Integrated Network (MAIN)	$1,489,300 (total)	August 2016–May 2020
Employee in Charge Portable Remote Terminal (EICPRT)	$3,200,400 (total)	September 2012–March 2019

NOTE: Funding level is for FY 2019 unless otherwise specified.
SOURCE: Federal Railroad Administration Office of Research, Development, and Technology 2019a.

6

Office of Research, Development, and Technology Support Functions

In addition to reviewing each of the four research divisions in the Federal Railroad Administration's (FRA's) Office of Research, Development, and Technology (RD&T), the Statement of Task calls for a review of and advice on the central office's support functions. As discussed in Chapter 1, the questions in the Statement of Task that concern these support functions ask whether RD&T

- Engages in planning that is guided by a well-defined mission with associated goals and priorities that reflect safety needs in the railroad industry (Question 3);
- Takes steps to evaluate and ensure the usability and likelihood of adoption of research results by the railroad industry (Question 10);
- Assesses the overall impact of the research and communicates the results to key stakeholders using means such as summative evaluation reports, technical reports, and conference presentations (Question 11); and
- Sets budgets and staffing levels that are suited to addressing established goals and priorities (Question 6).

To respond to these questions, the committee reviewed the means by which RD&T engages in, directs, and oversees

- Strategic planning to guide the program, including the articulation of goals and strategies for the identification of research needs; establishment of program priorities; pursuit of different kinds

of research (e.g., applied and knowledge-based research); dissemination, implementation, and evaluation of research results; and alignment of staffing and budget levels with these goals and strategies;
- Communications and other interactions with industry, other FRA offices, the research community, and railroad labor to identify priorities, recruit partners, and ensure that results are adopted and effective in the field; and
- Evaluations of the performance and impact of work of the individual divisions and the program overall.

In the committee's view, all four research divisions should engage in strategic planning, communications, and evaluation along with the RD&T management team, but the management team has a supportive role in providing the needed direction, guidance, and resources. Therefore, when reviewing these three general support functions, the committee also refers back to its observations and recommendations from the four division reviews. Strengths and weaknesses observed in their planning, communications, and evaluation can be indicative of how well RD&T is providing the needed support to the overarching research program.

Upon commencement of the study, the committee met with RD&T's senior management and division chiefs, who provided high-level presentations describing RD&T's mission and goals, as well as overviews of their focus areas, budgets, and staffing of the four divisions and program overall. The committee reviewed RD&T's planning documents, including the most recent Annual Modal Research Plan for FY 2019 (Federal Railroad Administration Office of Research, Development, and Technology 2018b), and asked the senior management team to explain how data on safety trends are used to inform priorities, staffing levels, and budget allocations. In subsequent meetings, the committee queried senior managers about how they engage in and guide the approaches used by the four divisions for communications and impact evaluations, including means used to communicate with and consult FRA's Office of Railroad Safety (RRS), other modal administrations within the U.S. Department of Transportation (U.S. DOT), freight and commuter railroads, railroad labor, and the broader research and technical communities.

Informed by these discussions and document reviews, as well as the observations and recommendations from the subcommittee reviews of the four research divisions (summarized in Box 6-1), the committee offers the following observations with respect to RD&T's strategic planning, communications, and evaluation support functions.

BOX 6-1
Observations and Advice from Reviews of the Four Research Divisions

Track and Structures

Value of Safety Data and Industry Collaboration in Project Selection

The Track and Structures Division (Track Division) budgets for the two research programs on track and structures and track–train interaction align with data on track-related derailment causes. Decision-support tools can be an effective means for developing and articulating the rationale for project selection, which, once recalibrated, should lead to even more effective means for project selection and even more effective communication of research priorities with industry and other audiences, especially if combined with other means such as periodic conferences with industry to discuss the basis for past project selections.

Reliance on Phased Procurement

The use of separate procurements for distinct phases of larger projects can be an effective means of reducing risk through the establishment of clear checks on project quality. However, this approach can slow progress on low-risk projects that have a higher likelihood of commercial viability and lead to a portfolio consisting of many active projects with a burdensome level of administrative challenges for program managers.

Advance Planning to Assure Widespread Deployment Capability

The willingness of railroads, suppliers, and others from industry to participate in a project is a clear sign that the research topic is important and the innovations being pursued by the research promise to have application in the field. Ensuring longer-term and more wide-scale deployment of successful innovations from research, however, may require even more front-end technology transfer planning to avoid deployment obstacles, such as the management of intellectual property, including user and data rights.

Recommendation

Ensure that technology transfer planning is sufficiently thorough and anticipatory at the outset of projects to take into account and manage the challenges that can hinder desired levels of deployment of research products and services, including the management of intellectual property such as user and data rights.

Human Factors

Trespassing and Suicide Countermeasures Program Holds Promise

All indications are that the Human Factors Division's ongoing trespassing and suicide prevention programs are coordinated effectively with the railroad industry. Because trespassing and suicide prevention are major concerns for operators

continued

BOX 6-1 Continued

of transit rail and highway systems, opportunities may exist for wider application of this knowledge through increased coordination with the Federal Transit Administration, Federal Highway Administration (FHWA), the public transportation industry, and state transportation departments.

The Cab Technology Integration Laboratory's Strategic Planning Promises More Industry Application and Collaboration

The Human Factors Division has successfully developed its strategic plan for the Cab Technology Integration Laboratory and placed greater emphasis on industry consultation, collaboration, and communication. If continued as planned, this plan will help ensure that this world-class human factors laboratory is used to the maximum extent to address many safety issues.

Phasing Research into Small Projects Has Pros and Cons

The Human Factors Division seeks to maximize the use of funds for research by staging projects in phases, which allows funding to be spread across multiple budget cycles and can provide a checkpoint mechanism to monitor project progress and modify research plans as necessary. A disadvantage is that shorter duration projects may not sustain the development of a talent pool of budding human factors researchers whose involvement in projects is essential for a research management agency that is dependent on the expertise of contractors.

The Short Line Safety Institute Is a Success Story

The Short Line Safety Institute has provided a needed focus on improving the organizational safety culture of smaller freight railroads and illustrates how the Federal Railroad Administration's (FRA's) collaborations with industry can lead to cooperative solutions to problems and generate support for implementation across the industry.

Opportunities Remain for Increased Communication and Dissemination of Research Results

The importance of the work conducted by the Human Factors Division does not appear to be matched by its capability to communicate and disseminate the results. Greater use of communication means such as e-newsletters, webinars, presentations, and workshops in conjunction with major industry conferences and technical events would seem to be warranted to ensure that the products of the division's human factors research are known and available to potential users, including those in the U.S. rail transit and highway sectors. Ultimately, these efforts and those in the other divisions will only demonstrate value if there are observable improvements in safety trends that can be attributed to the Office of Research, Development, and Technology's (RD&T's) programs.

Recommendations

- The Human Factors Division should become more involved in the design, development, and programming of research projects across FRA's RD&T portfolio.

- The Human Factors Division should engage more frequently with other U.S. Department of Transportation (U.S. DOT) modal administrations and other relevant federal agencies to identify opportunities for its work to inform, and be informed by, their human factors–related challenges and research, and to collaborate on the design and conduct of relevant research and the dissemination of those research results and products that have broad, multi-modal application.

Rolling Stock

Rolling Stock Safety Spans a Wide Domain That Demands Consideration and Balancing of Multiple Interests When Programming Research

The wide purview of the Rolling Stock Division has led to a large and varied research portfolio—as diverse as wheel failure research, fire prevention, passenger railcar structural integrity, and tank car impact testing—that responds to problems identified through examinations of causal factors reported in FRA incident data, legislative mandates, the rulemaking and enforcement requirements of FRA safety regulators, safety concerns identified in FRA and National Transportation Safety Board incident investigations, and other inputs.

Industry Collaboration Is Critical to Ensuring That the Rolling Stock Division's Research Capacity Is Used to Its Greatest Advantage

The Rolling Stock Division's data-driven and longstanding practice of industry-partnered research on railcar equipment and components was lauded by the industry representatives consulted for this review. However, their comments on the research programmed in some other areas, such as on wayside detection technologies, surfaced concerns about whether the pace of the division's research programming and execution is sufficient to keep up with the rate of technology development and deployment by industry in the field.

Recommendation

To better ensure that RD&T projects align not only with the most important safety problems but also focus on research needs that are best suited to the unique strengths of a government contract research program, the Rolling Stock Division should make industry consultations and collaborations a core feature of all research that will ultimately require industry acceptance and application of the results. In having so many diverse research responsibilities, such an alignment and focus is essential to ensuring the effective and judicious use of the division's limited research budget. Moreover, the division should prioritize projects based on safety data; these priorities should be used to determine the number of active projects commensurate with the division's funding level and allocated personnel.

Train Control and Communications

The Train Control and Communications Division's Work to Improve the Operational Capabilities and Performance of Positive Train Control Aligns with Its Safety Mission

continued

BOX 6-1 Continued

In recognizing the importance of efficient, precise, and reliable operations to achieving the safety promise of positive train control (PTC), the division has forged strong connections with the railroad industry to identify and articulate critical PTC-related issues requiring research and industry involvement in projects. While the legislative mandate for PTC deployment underpins this collaboration, it appears to have promoted collaboration across the division's train control and communications portfolio.

The Train Control and Communications Division's Focus on Automation, Intelligent Transportation Systems, Communications, and Sensor Technology Recognizes the Importance of Human Factors to Train Operations and Grade-Crossing Safety

Having such a wide breadth of responsibility—from furthering PTC to grade-crossing safety—the Train Control and Communications (TCC) Division has demonstrated creativity in harnessing advanced communications, sensors, intelligent transportation systems, and automation technologies to address human performance and behavior issues that can affect safety. Collaborations with other U.S. DOT agencies, such as FHWA and the Federal Motor Carrier Safety Administration, on using connected vehicle technologies to alert drivers to grade crossings exemplify this creativity.

Recommendation

While all of the RD&T divisions face obstacles to getting the results of their research published and disseminated, overcoming these obstacles is especially important for ensuring the timely application of the TCC Division's technology-oriented work. To this end, the TCC Division should make a concerted effort to ensure that research results are made available to industry and other users as quickly as possible to contribute to the advancement of PTC and other systems being deployed in the field.

STRATEGIC PLANNING

When asked about the status of RD&T's strategic planning, the committee was informed that a late-stage draft of the FY 2018–2022 strategic plan was pending internal (FRA/U.S. DOT) review. In not having access to this plan, the committee reviewed FRA's Annual Modal Research Plan for FY 2019 and concluded that it was not a strategic plan but rather a compendium of the various RD&T programs and projects. While the plan maps these programs and projects to the goals of U.S. DOT's strategic plan, it does not articulate agency priorities, strategies for pursuing them, or justifications for RD&T programs and budgets as one would expect from a guiding strategic plan.

Hence, at the time of this review RD&T did not have an up-to-date strategic plan and was presumably being guided in part by the FY 2013–2017

strategic plan issued in May 2013 (Federal Railroad Administration Office of Research, Development, and Technology 2013). That plan—to the extent that it remains operative and influential on current RD&T programs—describes strategies for stakeholder engagement and partnering, procurement, the identification of research needs and selection of projects, and the evaluation of programs and projects. As a model for future strategic planning, however, the committee determined that this plan needs improvement, not only by providing more complete descriptions of the strategies being pursued but also by giving the rationale for pursuing each.

The articulation of stakeholder communications and partnering strategies is a strength of the FY 2013–2017 plan, which states that stakeholder engagement is the cornerstone of a successful R&D program and that engagement with stakeholders throughout the life cycle of a research project is crucial to identifying, prioritizing, and implementing research that is both relevant and feasible to intended users.[1] The plan identifies key stakeholders inside FRA (e.g., RRS) and external to FRA (e.g., passenger and freight railroads, labor, and suppliers). The plan emphasizes the importance of conducting research in partnership with organizations such as the Association of American Railroads (AAR) and the American Public Transportation Association (APTA) and on co-funding and jointly conducting projects with industry to ensure research relevance and quality and to avoid duplication. As an example, the plan calls for ongoing collaborations with AAR to scan universities for technological developments that may have railroad application. However, it merits noting that the process of integrating input on research needs from external stakeholders during the development of the RD&T strategic plan is not part of a formalized process.

Likewise, the strategies for identifying research needs and prioritizing projects are well-explained and reasoned. In addition to industry engagement, emphasis is placed on using incident data and consultations with RRS for identifying safety research needs and project concepts. The plan also points to the importance of funding some novel research for the purpose of developing fundamental knowledge, although it does not explain how this goal should factor into prioritizations. An example of novel research includes the early development of machine learning for track inspection in 2002, as noted during an RD&T staff presentation (Carr 2019).

In meetings with the RD&T management team about priority setting, the committee was informed about the office's use of Decision Lens, a decision-support software program, to assist with project selection that had been in use for several years. The algorithm in the software scores candidate

[1] This point on stakeholder engagement was made in the *Committee for Review of the Federal Railroad Administration (FRA) Research, Development, and Demonstration Programs Letter Report: May 31, 2012* as RD&T was preparing its strategic plan for FY 2013–2017 (National Academies of Sciences, Engineering, and Medicine 2012).

projects based on weights assigned to various criteria and considerations such as whether a candidate research topic addresses a need identified through analysis of safety data and consultations with stakeholders, whether it aligns with U.S. DOT and FRA strategic priorities, and how much risk it presents in terms of cost and schedule. A benefit from the use of a decision-support tool such as this is the ability to produce a score that helps to communicate the rationale for selecting specific projects for funding. At the time of this review, however, this decision-support tool was not being used for such scoring because its weighting factors were undergoing review to account for changes in U.S. DOT strategic goals. The committee was thus unable to consider project prioritization scoring for RD&T's portfolio of active projects.

The FY 2013–2017 plan is not as effective in explaining RD&T procurement and evaluation strategies and their functional role and value. While it describes the mechanisms used for procurement, including contract research, grants, Broad Agency Announcements (BAAs),[2] and the stepwise phasing of projects into a series of smaller projects, it does not do enough to explain the reasons for each mechanism under different circumstances and for different purposes. As discussed in Chapters 2–4, phased procurement can lead to a burdensome administrative load or an overly broad set of project topics, which leads to a slowdown in deployment of safety benefits and questionable priority setting. The section on evaluation strategies points to the importance of conducting evaluations that are credible, relevant, and timely but lacks a common framework for how such evaluations should be conducted. Also noteworthy is that the plan does not provide—ideally at the outset—a compelling articulation of the role and value of FRA's RD&T, including the range of outcomes intended, which presumably consists of not only technology development to enhance safety but also information for decisions, operational solutions to problems, knowledge to support future research, technology transfer, and the development of a skilled pool of railroad safety researchers.

Another gap in the plan involves personnel strategies. Means for ensuring the effective allocation of staff and filling vacant positions in a timely manner should be part of a strategic plan, which would assist in fulfilling long-term needs in domain knowledge and talent among RD&T's personnel and key contractors. Although aware of the slow pace of the federal hiring process, the committee questions whether longstanding senior staff vacancies will ultimately hinder the work of the divisions. It is exceedingly critical to the safety mission of RD&T to ensure continuity in key leadership and project management positions.

[2] A BAA allows FRA to publicize a set of general research needs and to receive proposals from potential suppliers.

Although an updated strategic plan is apparently being drafted, its prolonged absence means that RD&T senior leadership may not be providing sufficient strategic guidance, direction, and support for the four research divisions. Indeed, the preceding reviews of the four divisions yielded examples of needs that a strategic assessment could surface and help resolve. The committee has recommended, for instance, that the Human Factors Division be given a more prominent role in the design, development, and programming of research projects across RD&T's portfolio—which requires cross-organizational strategies that can only be developed and implemented by the RD&T management team. The committee further recommended that the Track Division make more judicious use of phased project procurement to ensure that valuable research results are not delayed as a result of multiple procurements and to ensure that the number of projects under contract does not create oversight and administrative burdens that risk delays across the portfolio. An articulation of the purpose of such a phased procurement approach, and when it should be used, is warranted as part of a broader procurement strategy.

Another committee recommendation pertaining to the Track Division was for more thorough technology transfer planning at the outset of projects to take into account and manage the challenges that can hinder deployment of research products and services. A particular issue identified as being problematic—the management of intellectual property rights—is beyond the capabilities of the Track Division to resolve alone and requires strategic actions pursued by the RD&T management team in concert with other FRA offices.

While the committee expects its biennial review of the four divisions to help inform strategic planning, it is not a substitute for an ongoing and more comprehensive strategic planning capability. While there is evidence that RD&T has such a capability, the delays in releasing the plan can be problematic for executing the strategies and ensuring that they are sound. It is important to recognize that even if informal steps are taken internally to align with the draft plan, many of the strategies are likely to involve interests outside RD&T, including other FRA offices, the railroads and their suppliers, labor, and the research community. The opportunity for them to have input into the plan at a formative stage is essential.

COMMUNICATIONS

The committee was interested in understanding how, in practice not just in its strategic planning, RD&T demonstrates the importance of communication with industry, other FRA offices, the research community, and labor to identify priorities, recruit partners, and implement results. The FY 2013–2017 strategic plan placed a great deal of emphasis on these

connections and interactions for identifying research needs and priorities, partnering with industry, and ensuring that the research results are usable and applied. The results of that planning should now be evident in practice. The committee therefore asked senior management to identify the specific means by which RD&T consults and collaborates with other FRA offices, including RRS, the Office of Railroad Policy and Development (RPD), and the Office Safety Analysis; railroads, shippers, and suppliers; and technical experts from academia and research and consulting organizations.

Both in planning documents and from discussions with senior management, communications was described as integral to the program. Providing avenues for the broad array of stakeholders to communicate their research needs was characterized as critical to ensuring that the right problems are being targeted for research and that appropriate research mechanisms and procurement methods are being used (e.g., industry partnerships, BAAs, phased procurements). Communications was also described as being integrated into the entire project life cycle to ensure that the work is being done well and that the results will be used in the field to yield positive safety impacts. The committee was told that the divisions are directed to ensure that staff evaluate the progress of the research and usefulness of the results on an ongoing basis by partnering with stakeholders in the conduct of the work and by making a coordinated effort to disseminate the results to the railroad community. The committee's review of the work of the four divisions suggested that this direction is being followed, but gaps surfaced in certain aspects of communications, particularly in the area of dissemination (e.g., hastening publication review and enhancing the office's electronic library) that may warrant central office attention and support. As noted in Chapter 3, the eLibrary suffers from issues with retrieval of project reports and other technical difficulties. Moreover, it is concerning that a senior employee of a commuter rail line was unaware of the RD&T divisions and how their research products and services might have delivered safety benefits to this passenger service. The committee would be better placed to evaluate RD&T if the office could better demonstrate the influence of its research through measurable improvements in safety and operational data.

Asked to explain the approach to communications with the railroad industry, RD&T senior management pointed to several examples of the individual divisions engaging with railroads and suppliers; indeed, the subcommittees found many examples of such engagement when reviewing the work of the four divisions. The examples given by senior management, and those cited in the chapters of this report, show a wide variety of approaches being employed, including RD&T staff participating in AAR and APTA research and technical committee meetings, staff presentations at industry conferences, and the co-funding and joint conduct of projects, including

pilot projects to test and demonstrate the technologies and concepts in the field.

The RD&T management team, however, did not explain how it supports such communications activity with needed guidance and resources—for instance, by providing funds for staff to attend conferences and to convene workshops with stakeholders. In the absence of an updated strategic plan, it proved difficult for the committee to assess the role that RD&T plays in supporting communications. While the FY 2013–2017 plan emphasizes stakeholder engagement and partnering, there is sufficient variability in the communication mechanisms used by the divisions to suggest that division-level initiative, not support and guidance from the management team, is central to building and sustaining stakeholder communications. An example of a meaningful communications strategy to further strengthen stakeholder communication would be support for an open and free exchange of ideas on a regular basis between RD&T and the railroad industry about safety improvements outside of the enforcement context.

With regard to interactions with other FRA offices, the Annual Modal Research Program states that RD&T "works closely with FRA RRS to provide the basis for science-based requirements, standards, and recommendations that have been tested in real-world environments with the help of companies and organizations who will adopt and use the technology" (Federal Railroad Administration Office of Research, Development, and Technology 2018b, 106). In asking about the means by which these consultations and those with other FRA offices are carried out, the committee was told that interactions have occurred on an informal basis for years but that since 2017 the RD&T division chiefs and officials from RPD and RRS have been meeting regularly to discuss safety and research needs. To further expand communication with RRS, the RD&T division chiefs attend week-long RRS offsite training sessions on functions such as track and equipment inspection, which are intended to improve their understanding of the practical challenges and needs of FRA enforcement.

Hence, the evidence from the reviews of the four research divisions suggests that they maintain regular and largely effective communication with other FRA offices and with industry to aid in the identification of priorities, recruit partners, and implement research results. While the supportive role of RD&T senior management in ensuring such engagement is not clear, there appear to be opportunities for more support to fill gaps, particularly in the timely and broader communication of research results. For instance, following the review of the Rolling Stock Division's work the committee recommended that the division make industry consultations and collaborations a core feature of all research to make more judicious use of its limited research budget in a field in which there are so many research needs. Likewise, the committee recommended that the Train Control and

Communications Division make a concerted effort to ensure that its research results are made available to industry and other users as quickly as possible given the rapid pace of information and communications technology development and deployment in the field. In its review of the Human Factors Division, the committee recommended that staff consult regularly with other U.S. DOT modal administrations—as well as other agencies that conduct research into human factors such as the Occupational Safety and Health Administration in the U.S. Department of Labor, the Human Factors Program in the Office of Safety and Mission Assurance at the National Aeronautics and Space Administration, and the U.S. Department of Defense Human Factors Engineering Technical Advisory Group—to identify opportunities for the division's work to inform, and be informed by, work in the other modes and federal agencies. RD&T could be proactive in trying to identify where such additional communications efforts are desirable and provide the needed guidance and resources to support and sustain them.

EVALUATION

Stakeholder engagement in the selection of projects, conduct of work, and dissemination of results is viewed as providing built-in evaluations. Industry, for instance, is not likely to prioritize research topics that do not address needs in the field or that have minimal prospects for adoption. Likewise, industry is not likely to agree to co-fund or continue to collaborate on projects that are poorly planned and poorly executed. The quality and relevance of many products, concepts, or innovations developed by research can be ascertained in large part by the extent to which a railroad or supplier partner adopts them and promotes their use across the broader industry. Thus, RD&T senior leadership and its divisions depend on close connections with stakeholders to ensure that the work is relevant and that it remains on course and has impact when completed.

The committee agrees that stakeholder connections are desirable in large part because they ground the research program in reality. There is ample evidence—including projects sampled in this report—that the four research divisions cultivate and nurture such connections and that by doing so they have produced many deployable products for improving railroad safety. However, there are many reasons for engaging in formal and deliberate evaluations and for not relying solely on this built-in process for ensuring program effectiveness. One practical reason is that FRA research seeks to do more than develop deployable safety-enhancing products, services, and operational concepts. Research is programmed to inform agency decisions (e.g., regulatory decisions), find operational solutions to problems, create knowledge to support future research, and help build and sustain

the U.S. railroad research workforce and experimental capacity. Another reason is that the evaluations themselves can have many purposes—for instance, they can be undertaken to assess the conduct of the work itself, identify areas where improvements are needed in programs and the organization, establish effective oversight, and ensure compliance. Evaluations help FRA set priorities and make adjustments to research procedures, and they can be used to communicate the value of the research to a variety of audiences internal and external to the agency, including Congress.

While responsibility for undertaking program-wide evaluations clearly lies with RD&T's divisions, the management team can also support the divisions in conducting their own program and project evaluations. For instance, the management team could develop a common evaluation framework that distinguishes among research outputs, outcomes, and ultimate impacts. Similarly, they could report more extensively on industry adoption of RD&T results, as was noted for deployment of autonomous track geometry measurement systems in Chapter 2, though otherwise briefings to the committee lacked such instructive detail. Measures of research outcomes that relate to the value to the public (safety and efficiency), government (scientific and wholistic bases for actions), labor (safety and ergonomics), or industry (safety, efficiency, and profitability) are imperative. Because FRA's mission is to improve railroad safety, complete evaluations would naturally also determine whether outputs and outcomes produce safety benefits—a vital consideration in program evaluation.

As noted above, the FY 2013–2017 strategic plan is short on details describing how RD&T senior management engages in and supports program and project evaluations. When the committee asked senior management about methods of evaluation, a common response was to cite the importance of having continuous input and reviews by stakeholder panels. When asked whether RD&T requires that each project have built-in features to aid in evaluation, senior management reported that each is required to provide status reporting, usually on a monthly basis. RD&T has been developing a handbook for staff that contains guidance on conducting project evaluations, including reporting on key indicators of project performance. The standardized report requires expenditure data, work in progress percentages on deliverables, and summaries of recently completed and planned activities. The committee learned that the management team has been building internal capabilities for program evaluation to ensure that projects have the highest probability of delivering benefits, but few additional details were provided on the status and accomplishments of this initiative.

A general sense of the committee is that the management team is interested in conducting more informative evaluations as well as providing the divisions with more guidance and capacity for conducting their own

evaluations. The RD&T senior management team is responsible for leading the group to establish effective long-range metrics, including periodic benchmark exercises with other agency research units. It merits noting that FRA's sister agency, FHWA, has implemented a program and project evaluation framework for its R&D program that may serve as model for RD&T (Federal Highway Administration 2018).

RECOMMENDATIONS

The committee's review of the support functions that RD&T should fulfill under the rubrics of strategic planning, communications, and evaluation surfaced both strengths and weaknesses. A major weakness is the lack of an updated strategic plan that articulates the management team's role in supporting the work of the four divisions and provides strategies for implementing that role. In the absence of such a plan, the committee found it difficult to understand how RD&T senior management guides, oversees, funds, and otherwise supports the work of the four divisions. More enlightening, in the committee's view, were the reviews of the individual divisions. They provided insight into where additional support by RD&T senior management is needed. Hence, the recommendations offered next can be viewed as pertinent to strengthening the supportive role of the RD&T management team—especially in strategic planning—and addressing several of the division-level needs identified in the earlier chapters.

- RD&T should engage in ongoing strategic planning that not only articulates agency priorities, strategies for pursuing them, and justifications for its programs and budgets, but also clearly defines the support functions that are its responsibility and explains how those functions will be implemented. The plan should provide strategies for nurturing new technologies and techniques, such as the application of machine learning to railroad applications. The plan should also provide direction for assessing the impact of the research program over time, such as for the period covered by the most recent strategic plan, and it should articulate strategies for future impact assessments. Because many of the strategies in the plan are likely to involve interests outside RD&T, including other FRA offices, the railroads and their suppliers, labor, and the research community, such stakeholders should be formally invited to offer input early in the planning process.
- RD&T should make more judicious use of phased project procurement to ensure that valuable research results from well-scoped, low-risk projects are not delayed as a result of multiple procurements and that the number of projects under contract does not

create oversight and administrative burdens that risk delays across the portfolio.

- RD&T should consult the four research divisions about their communications needs and challenges and look for opportunities where support by the management team would be advantageous, such as in providing resources for staff travel and participation in industry conferences and for convening annual, multi-day stakeholder workshops for sharing research results, identifying and prioritizing research needs, and exploring opportunities for collaboration in the conduct of research and in the demonstration and deployment of research results.
- RD&T should work to develop a more comprehensive approach to program and project evaluation, including the development of a common evaluation framework that can be used by the four divisions to assess outputs, outcomes, and ultimate safety impacts of their work. FRA should adopt best practices that become apparent through periodic benchmarking exercises with other agencies in U.S. DOT and other federal research agencies about their research program evaluation methods and support functions, including FHWA.

Note: While the study committee's report was in peer review, RD&T released its Research, Development, and Technology Strategic Plan for 2020–2024 (Federal Railroad Administration Office of Research, Development, and Technology 2020b). Unfortunately, the release occurred too late in the study process for the committee to thoroughly deliberate over and critique the document. One general observation that can be made, however, is that the strategies identified in the plan are similar to those of the earlier plan, with the exception of a new strategy for addressing safety risks in rural areas. A notable improvement is the inclusion of benchmark safety outcomes or goals as well as other metrics to evaluate a project's success, such as reduce the cost per mile of recording track conditions. Apart from these observations, however, the updated plan does not appear to address the points raised above in the recommendation on strategic planning. It also bears noting that for 3 years RD&T has not had the benefit of this refreshed strategic plan.

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Appendix A

Railroad Safety Statistics

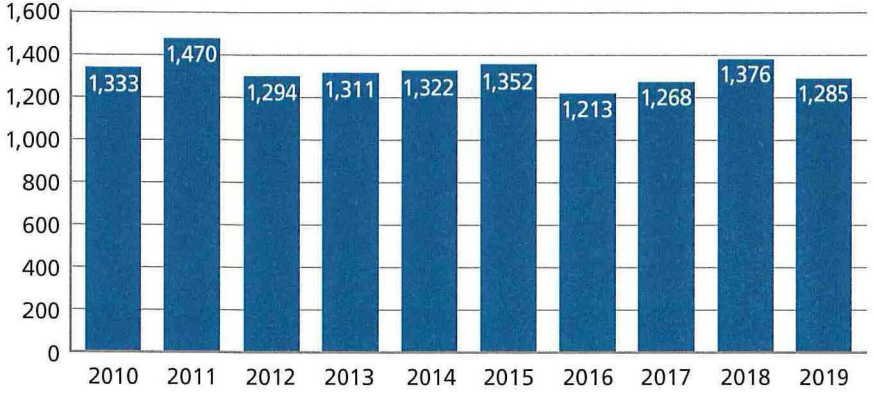

FIGURE A-1 Total number of train derailments reported to the Federal Railroad Administration.
SOURCE: Federal Railroad Administration 2020a.

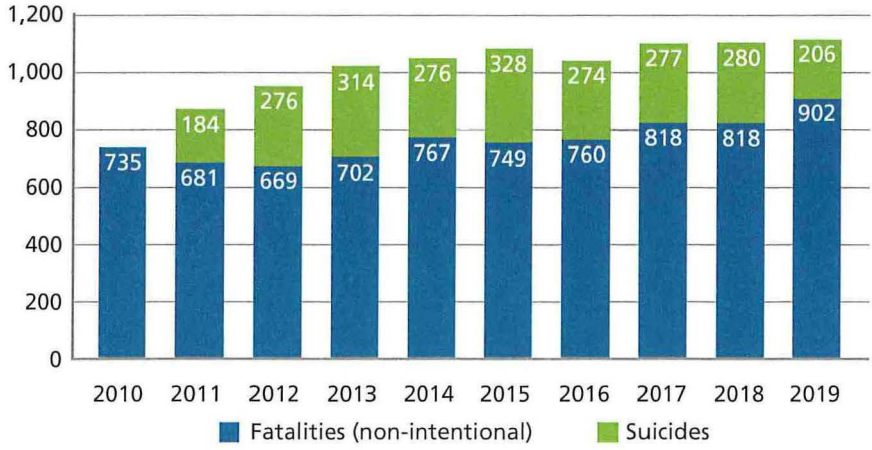

FIGURE A-2 Total Federal Railroad Administration–reportable fatalities, including suicides, as of July 1, 2011.
NOTES: Data for suicides not available in 2010. Data for 2018 and 2019 are subject to change contingent on updates from medical examiners' reporting.
SOURCES: Federal Railroad Administration 2020a,c.

Appendix B

Committee for a Review of the Federal Railroad Administration's R&D Program Study Participants

May 14–15, 2019
Keck Building

Federal Railroad Administration (FRA) Office of Research, Development, and Technology (RD&T) Presenters:

- Maryam Allahyar, Director, RD&T
- Sam Alibrahim, Chief, Train Control and Communications Division
- Starr Kidda, Chief, Human Factors Division
- Gary Carr, Chief, Track and Structures Division

October 17, 2019
Teleconference

Human Factors Participants:

- Tim Tenne, Senior Director, Compliance, Certification and Quality Assurance, Amtrak
- Lawrence Fleischer, Director, Ergonomics and Safety, BNSF Railway Company (BNSF)
- Aaron Ratledge, General Director, Operating Practices, Safety and Technical Training, BNSF
- Jason Myers, Manager, Operating Rules, Norfolk Southern
- Kirk Gill, Senior Manager, Regulatory Affairs, Canadian National Railway (CN)

- Tom Meierhoff, Director, Rules and Training, Iowa Interstate Railroad
- Carl Belke, Executive Consultant, D&H Rail Consulting LLC (retired Vice President, Western New York and Pennsylvania RR)
- Eric Holton, Human Factors Engineer, Compliance & Environmental, Genesee & Wyoming Inc.
- Ken Glover, Senior Vice President, Safety, Compliance & Environmental, Genesee & Wyoming Inc.
- Ron Hynes, Assistant Vice President, Technical Services, Association of American Railroads (AAR)
- Jeff Moller, Assistant Vice President, Transportation Systems & Practices, AAR
- Justin Vonashek, Safety Chief, Metro-North
- Lisa Staes, Director, Transit Safety and Workforce Development Programs, Center for Urban Transportation Research, University of South Florida
- Joshua McCormack, Manager, Safety Management Systems, Maryland Department of Transportation
- Alex Lang, Vice President, Equipment and Technology, Carload Express, Inc.

Rolling Stock Participants:

- Darrell Iler, Senior Engineer Mechanical—Rail Cars, CN
- Ron Hynes, Assistant Vice President, Technical Services, AAR
- Jeff Moller, Assistant Vice President, Transportation Systems & Practices, AAR
- Michael Trosino, Senior Director, Clearances and Inspections, Amtrak
- Narayana Sundaram, Senior Director, Engineering and Commuter Rail Operations, American Public Transportation Association
- Dean Del Peschio, Director, MARC Train Service

November 21–22, 2019
Keck Building

- Gary Fairbanks, Staff Director, Motive Power & Equipment Division, Rolling Stock, FRA
- Khaled Zaazaa, Track, FRA
- Frank Frey, General Engineer, Signals and Train Control, FRA
- Miriam Kloeppel, Staff Director, Risk Reduction Program Division, FRA
- Maryam Allahyar, Director, RD&T, FRA

December 23, 2019
Teleconference

- Les Fiorenzo, retired, former Regional Administrator, FRA

December 30, 2019
Teleconference

- Hilary Konczal, Chief Safety and Environmental Officer, Metra

January 9, 2020
Teleconference

- Muriel Friday, Director, Rail Operations at Capital Metropolitan Transportation Authority

January 24, 2020
Teleconference

- Jo E. Strang, Senior Vice President, Safety and Regulatory Policy, American Short Line and Regional Railroad Association

January 30, 2020
Teleconference

- Allan Zarembski, Director, Railway Engineering and Safety Program, Professor, Civil and Environmental Engineering, University of Delaware

February 4, 2020
Teleconference

- Andrew Liu, Research Scientist, Massachusetts Institute of Technology

February 6, 2020
Teleconference

- Riley Edwards, Senior Lecturer and Research Scientist, University of Illinois at Urbana-Champaign

February 7, 2020
Teleconference

- Mehdi Ahmadian, J. Bernard Jones Professor of Mechanical Engineering, Virginia Polytechnic Institute and State University

February 11, 2020
Teleconference

- Christopher P.L. Barkan, Professor and George Krambles Director, Rail Transportation and Engineering Center, University of Illinois at Urbana-Champaign

February 20, 2020
Teleconference

- Hai Huang, Associate Professor, Engineering, Penn State Altoona

Appendix C

Study Committee Biographical Information

John M. Samuels, Jr. (NAE) is President of Revenue Variable Engineering, LLC, working primarily in the areas of science dealing with railroad engineering, and has done work both nationally and internationally dealing with railroad infrastructure maintenance, asset life extension, and the design of advanced sensor systems used to track the maintenance condition of railroad rolling stock. Before retiring from Norfolk Southern Corporation in March 2006, he was Senior Vice President for Operations Planning and Support, the position he held since March 2000. He joined Norfolk Southern in January 1998, as Vice President, Operations Planning and Budget, after spending 20 years at Conrail, the major northeastern freight railroad in the United States. During his career at Conrail, he held successive positions of Assistant Vice President Industrial Engineer–Transportation, Vice President Continuous Quality Improvement, Vice President Engineering, Vice President Mechanical, and Vice President Operating Assets, in charge of the planning and maintenance of Conrail's 1,800 locomotives, 64,000 railcars, and 18,000 miles of right-of-way.

Dr. Samuels served as Past Chairman of the Executive Committee of the Transportation Research Board, Past Chairman of the Association of American Railroads Research and Technology Working Committee, and Past Chairman of the North American Joint Positive Train Control (PTC) project. He also served on the advisory board for the Vital PTC System development at the Transportation Technology Center, Inc., in Pueblo, Colorado. He remains involved in engineering education through the National Academy of Engineering and in the past served on the Dean's Advisory Committee of Old Dominion University Engineering Programs. He is a

past Chairman of the Accreditation Board for Engineering and Technology Industrial Advisory Committee, which sets the standards for college level engineering programs in the United States.

Dr. Samuels was elected to the National Academy of Engineering (NAE) in 1996, was The Pennsylvania State University's Outstanding Engineering Alumni in 1994, and was a Fellow of the Institute of Industrial Engineers in 1999. He remains an advisor to the NAE on national transportation infrastructure issues involving railroads. He earned an M.S. and a Ph.D. from The Pennsylvania State University and a B.S. from the GMI Engineering and Management Institute (now Kettering University).

Melvin Clark is Senior Consultant at LTK Engineering Services, which specializes in passenger rail vehicle and systems engineering. Before LTK, for nearly four decades he managed rail signal design, track and infrastructure enhancements, railroad operations, rail systems maintenance, and vehicle programs at passenger and freight rail operators such as the Norfolk Southern Railroad, Capital Metropolitan Transportation Authority, Greater Cleveland Regional Transit Authority, and Los Angeles County Metropolitan Transportation Authority. His professional affiliations include the American Railway Engineering and Maintenance-of-Way Association, Eastern Signal Engineers, and Signal Training Consortium. He served on several Transit Cooperative Research Program panels for the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine. He earned a B.S. in electronics management from Southern Illinois University.

David B. Clarke is Executive Director of the University of Tennessee, Knoxville, Center for Transportation Research, where his responsibilities include administration, teaching, and sponsored research. His 39 years in the transportation field include management or participation in numerous research projects; teaching undergraduate and graduate level courses in roadway design, traffic engineering, transportation planning, railway design, and engineering systems; and experience in engineering design, construction, and project management. He is well known for his work in rail transportation, which includes teaching, research, and design experience. He is internationally active in efforts to promote railway research and education. He is active in professional associations, including as member and past chair of the standing committee on rail freight transport at the Transportation Research Board, the American Society of Civil Engineers (past Chair, Rail Transportation Committee), the American Public Works Association, and the American Railway Engineering and Maintenance-of-Way Association. He is a registered engineer in Tennessee and South Carolina. He holds a B.S., M.S., and Ph.D. in civil engineering (transportation) from the University of Tennessee.

Philip J. Daum is a Principal at Engineering Systems, Inc. He specializes in mechanical engineering, research, development, and experimental testing. He conducts complex, multidisciplinary research and accident investigations pertaining to freight and transit railroads, cargo and portable tanks, transportation equipment, and hazardous materials. He investigates reliability, durability, crashworthiness, security performance, and regulatory compliance. His industrial experience over 39 years includes design of railroad rolling stock, trucks, brakes, draft systems, valves, pressure relief devices, safety equipment, and operating systems. He is also experienced in technology evaluations, intellectual property analysis, equipment qualification, health monitoring, and maintenance. He served on the National Academies of Sciences, Engineering, and Medicine's Committee on the Review of Department of Transportation Testing of Electronically Controlled Pneumatic Brakes. He received a B.S. in mechanical engineering from the University of Illinois at Urbana-Champaign and holds professional engineering licenses in Illinois and California.

Eric Gehringer is Vice President of Engineering at Union Pacific Railroad. He is responsible for maintaining and hardening the company's infrastructure; leading the design, construction, and maintenance of track, structures, and signal systems; and ensuring safe and efficient movement of trains. He previously served as the Assistant Vice President of Track Programs responsible for renewal of track infrastructure. He has held various positions in the Operating Department's Engineering Department. Before Union Pacific, he worked at Northwest Airlines and Daimler Chrysler. He holds a B.S. in aerospace engineering from Saint Louis University and an M.B.A. from the University of Nebraska.

Judith Gertler was Division Manager for QinetiQ North America from 1996 to 2012. There she managed the group conducting human factors research projects related to transportation systems. Her research involved work schedule–related fatigue, training on responding to locomotive crashes, safety rule compliance, impaired drivers, and many other transportation safety issues. Since 2012, she has been self-employed as a consultant, analyzing work schedules for fatigue risk, developing fatigue risk management programs, and facilitating focus groups for transportation safety products and issues. She holds an M.S. in industrial administration from Carnegie Mellon University.

Sharon Harmsworth retired from TTX in 2019 as Vice President of Equipment. TTX is North America's leading provider of railcars and related freight car management services. As Vice President of Equipment, she was responsible for railcar and component engineering as well as

maintaining TTX's fleet of more than 225,000 railcars. Before joining TTX, she was Vice President of Engineering at Electro-Motive Diesel, which is a leading manufacturer of locomotives. She has worked in the rail industry for more than 30 years. She earned a B.S. in industrial and systems engineering from Ohio University and an M.S. in engineering management from Northwestern University.

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Ian P. Savage is Professor of Instruction in the Department of Economics and the Transportation Center at Northwestern University, where he has worked since 1986. His research has centered on urban public transportation and transportation safety. He has conducted research into safety performance and the effectiveness of safety regulations in most modes of transportation with an emphasis on the trucking and railroad industries. He has served on the organizing committees of local, national, and international professional organizations including as President of the Transportation Research Forum (2017–2018). He was a member of the Transportation Research Board (TRB) committee for the study of the domestic transportation of petroleum, natural gas, and ethanol (2015–2017), and is currently a member of the TRB Standing Committee on Highway/Rail Grade Crossings. He was also a member of the TRB Committee for Review of the Federal Railroad Administration Research, Development, and Demonstration Programs from 2007 to 2011. He has a B.A. in economics from the University of Sheffield and a Ph.D. from the University of Leeds.

Jo E. Strang is Senior Vice President, Safety and Regulatory Policy with the American Short Line and Regional Railroad Association (ASLRRA). At ASLRRA, she advises and represents the short line industry nationally in regulatory matters. Before joining the association in 2013, she held the highest career office with the Federal Railroad Administration (FRA) serving as the Associate Administrator for Railroad Safety/Chief Safety Officer. In that position, for which she was the longest serving in FRA history, she was responsible for all aspects of railroad safety in the United States. She has testified before Congress many times on safety and security issues. She holds a Presidential rank award along with numerous other awards. She earned a B.A. from the University of Cincinnati in economics and an M.S.A.E. in public policy economics from Marquette University.

French F. Thompson III is General Director of Commuter Construction for the BNSF Railway Company (BNSF). The role encompasses leading BNSF's commuter construction franchise associated with expanded commuter development across the west coast, inclusive of Sound Transit, Caltrain, Metrolink, and various Amtrak routes. In addition, he is part of BNSF's team for coordination and collaboration with the development and implementation of the California High-Speed Rail system in the central valley and the Los Angeles Basin. He also leads BNSF capital expansion and economic development design and construction throughout the west coast. Before being appointed to his current role, he served as BNSF's Director of Public Projects and System Design. His role encompassed facilitating BNSF's coordination and collaboration with public transportation agencies primarily focused on grade-crossing safety and transportation infrastructure intersecting or parallel to BNSF. The System Design team focused on long-range project management efficiencies, standardization, and talent development and training for BNSF's Engineering Services and Structures department. His professional memberships include the American Society of Civil Engineers, American Railway Engineering and Maintenance-of-Way Association, and National Society of Black Engineers. He is a member of the Transportation Research Board committees on Grade-Crossing Safety, Freight Rail Transportation, and Freight Transportation. He holds a B.S. in applied physics from Morehouse College and a B.S. in civil engineering from the University of Michigan.

David Thurston is Chief Engineer–Train Control for Canadian Pacific Railway. He has been involved in systems engineering for more than 40 years, emphasizing design, construction, and operations of railroad and transit systems. He is an Honorary Fellow and Country Vice President for the North American Section in the Institution of Railway Signal Engineers,

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Vincent G. Verna serves the Brotherhood of Locomotive Engineers and Trainmen (BLET) as Director of Regulatory Affairs, a position to which he was appointed in 2011. In 2014, he was elected to the position of Alternate Vice President and National Legislative Representative of BLET. As Director of Regulatory Affairs, he represents BLET on numerous collaborative endeavors, such as the Railroad Safety Advisory Committee (RSAC) with the Federal Railroad Administration (FRA). He represents the interests of BLET members in all regulatory matters, including those before the U.S. Department of Transportation, the National Mediation Board, the National Transportation Safety Board, and the Transportation Security Administration, among others. He prepares the union's responses to various agencies' proposals for rulemakings and proposed rules, and he prepares responses to petitions for waiver from compliance with FRA regulations. He served as Chairman of the Arizona State Legislative Board from 2008 until 2011. Since 2006, he has been active on various RSAC Working Groups. He holds a B.S. in history from California State University at San Bernardino and an M.S. in legal and ethical studies from the University of Baltimore.

Lisa Wilson is Senior Director of Advanced Train Control Systems and Operations for Norfolk Southern Corporation (NS), where she has

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